Faculty of Electrical Engineering and Technology

IOT BASED AUTOMATIC OBJECT COLOR SORTER USING A ROBOT ARM AND MICROCONTROLLER

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Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours

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IOT BASED AUTOMATIC OBJECT COLOR SORTER USING A ROBOT ARM AND MICROCONTROLLER

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DEDICATION

With gratitude and utmost respect, I extend my sincere appreciation to my esteemed parents for their unwavering love, steadfast support, continuous encouragement, and selfless sacrifices that have shaped the trajectory of my life. This academic achievement stands as a testament to the profound impact of their dedication. I express my deepest gratitude to the entire faculty, with special acknowledgment to my esteemed supervisor, Ts.Mohd Razali Bin Mohamad Sapiee, whose mentorship has been pivotal to my academic growth. I would like to convey my appreciation to all lecturers who have played a crucial role in my academic journey, particularly during the research phase. Their guidance has been instrumental in refining my research findings. I am also grateful to my friends for their constant encouragement and camaraderie throughout this journey. This project stands as a testament to the collective efforts of my loved ones, friends, and the mentorship of my supervisor, as well as my personal dedication to academic excellence.

ABSTRACT

This comprehensive report outlines the development of a cost-effective IoT-driven automated object sorting system, incorporating a robot arm and microcontroller. Specifically designed to address financial constraints in educational environments, the project introduces an affordable robotic arm tailored for educational purposes, enhancing students' understanding of robotics. The system leverages IoT sensors to gather real-time data on color recognition, object positioning, and sorting progress, facilitating precise control of the robot arm and microcontroller for accurate and efficient sorting operations. Key project objectives encompass the creation of a robot arm kit with color-detection capabilities, the design of a holistic system for object sorting with mobile phone control, and the implementation of hardware, software, IoT integration, and sorting algorithms. The prototype comprises an articulated robot arm managed by an ESP32 microcontroller, a TCS3200 color sensor for precise color detection, and an IoT platform for continuous monitoring. Successfully meeting its objectives, this project not only exemplifies the potential of IoT integration in industrial automation but also represents a significant advancement in automated sorting systems, highlighting the pivotal role of IoT in elevating accuracy and efficiency across diverse applications in the field.

ABSTRAK

Laporan ini merincikan pembangunan sistem penapisan objek automatik IoT yang ekonomi, menggunakan lengan robot dan mikropengawal. Projek ini bertujuan menangani kekangan kewangan dalam persekitaran pendidikan dengan menyediakan lengan robot yang berpatutan untuk tujuan pendidikan dan meningkatkan pemahaman pelajar terhadap robotik. Dengan mengintegrasikan sensor IoT, sistem ini mengumpul data masa nyata tentang pengenalan warna, kedudukan objek, dan kemajuan penapisan, membolehkan kawalan yang tepat terhadap lengan robot dan mikropengawal untuk penapisan yang tepat dan cekap. Objektif utama melibatkan pembangunan kit lengan robot dengan keupayaan pengesanan warna, reka bentuk sistem komprehensif untuk penapisan objek dengan kawalan telefon bimbit, dan pelaksanaan perkakasan, perisian, integrasi IoT, dan algoritma penapisan. Prototaip ini merangkumi lengan robot bersendi yang dikawal oleh mikropengawal ESP32, sensor warna TCS3200 untuk pengesanan warna yang tepat, dan platform IoT untuk pemantauan berterusan. Berjaya mencapai objektifnya, projek ini menunjukkan potensi integrasi IoT dalam automasi industri, menandakan kemajuan yang ketara dalam sistem penapisan automatik yang menonjolkan peranan penting IoT dalam meningkatkan ketepatan dan kecekapan di pelbagai aplikasi dalam bidang ini.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter will discuss the project's basic concepts. It will include the project background, problem statement, objectives, and scope of work. In addition, a simple work flow will be explained, from the start of operation to the end. This project is mostly comprised of Internet-of-Things (IoT) devices, which are required to achieve the Industry Revolution 4.0 (IR 4.0).

1.2 Background

The term robotics was coined by Czech writer Karel C apek in his play R.U.R. Rossum's Universal Robots, which was published in 1920. A robot is a self-aware, physically embodied machine. To a certain extent, a robot can do tasks autonomously. A robot can also be used to sense and manipulate its environment. Sensors prevent robots from collapsing into objects. That is why a sorting robot mule can keep an eye on you, follow you, and ship your stuff around [1].

All industries are getting more automated in the age of robotics and automation in order to achieve faster development and growth. A robot is an electromechanical machine that decreases the need for human labor while increasing efficiency. It is a real-time machine that uses computer programming to execute tasks in the allotted time [2].

A robotic arm is a sort of mechanical arm that is usually programmable. The arm can be the sum of the mechanism or it might be part of a larger robot. It is similar to the shape of a human arm. It is made up of a vertical column that swivels around the base thanks to a T-joint. The R-joint (shoulder joint) is placed at the top of the column. An elbow joint (another R joint) serves as the output link.

Robots are commonly used for welding, painting, assembling, pick and place for printed circuit boards, packing and labelling, palletizing, product inspection, and testing, all of which require a high level of endurance, speed, and precision. They can help in material handling. Industrial robots are classified into six types: cartesian, SCARA, cylindrical, delta, polar, and vertically articulated. There are, however, various other types of robot configurations. Each of these sorts has a unique joint configuration.

A basic robotic arm consists of seven metal segments connected by six joints. The computer directs the robot by turning individual step motors attached to each joint (some larger arms use hydraulics or pneumatics). Motion sensors are used by the robot to ensure that it moves just the proper amount.

They are also used for jobs that are too unclean, dangerous, or monotonous for people. Robots are widely employed in manufacturing, assembly and packaging, transportation, earth and space exploration, surgery, armament, laboratory research, and mass production of consumer and industrial goods.

Industrial robots, for example, are frequently built to perform repetitive jobs that would be difficult to accomplish with a human-like construction. A human operator can control a robot remotely, sometimes from a long distance.

1.3 Problem Statement

In today's educational system, most students are unable to obtain a better education because some robotic arms are prohibitively expensive and cannot be afforded by all. Typically, robotic arms are held by large corporations that require a significant amount of time in production. The majority of robotic arms on the market share the same features. The design does not encourage pupils to broaden their knowledge and keep up with robotic advancements. They will learn the fundamentals without being aware of the robotic potential.

A lower cost does not imply that it can bear a lot of stress, especially in the case of a robotic arm. Throughout the years, the student will employ a robotic arm for their studies. With cheaper comes the challenge of finding replacement parts if one of the components breaks. So, for this project, the previously mentioned project will be neutralised, and a robotic arm suited for instructional purposes will be constructed.

Create a robot arm that picks and sorts objects based on their color using a color sensor. The robot arm should be able to recognise the color of the object, pick it up with a gripper, and move it to the correct location based on its color. The system should be able to sort objects based on multiple colors and handle a wide range of object sizes and shapes. The project should also include a user interface that allows users to enter sorting criteria and track the robot arm's progress. The goal is to develop a dependable and efficient system that can be used in industrial settings for automated product sorting and distribution.

1.4 Project Objective

- To develop a robot arm kit with the capability to detect and distinguish different colors using a color sensor.
- To design and build a comprehensive system featuring sensor for object sorting progress with mobile phone control for the precise manipulation of the robot arm.

- To validate the sorting accuracy and efficiency of the IoT based color sorter through comprehensive testing, ensuring reliable object detection and precise manipulation by the robot arm.

1.5 Scope of Project

IoT Based Automatic Object Color Sorter using a Robot Arm and Microcontroller involves hardware and software implementation, IoT integration, item sorting algorithm creation, and mobile application development. The hardware implementation includes developing and integrating physical components such as the robot arm, microprocessor, IoT sensors, and colour recognition module. The software implementation includes programming the microcontroller for control and building algorithms for colour recognition and sorting decisions. The IoT integration process comprises setting up and configuring IoT sensors for real-time data collection.

The prototype for this project is separated into three major parts: the robotic arm, the object positioning system, and the detection of colour blocks. The robotic arm has an articulated design with four degrees of freedom (DOF). The ESP 32 microcontroller was chosen for this project to control the movements and activities of the robotic arm.

Colour blocks that function as sensing blocks are used in the item placement system. The TCS3200 colour sensor was chosen for this project because it is capable of recognising colours accurately. The system's colour blocks are specifically created with the colours red, blue, and green, which correspond to the colours visible by the TCS3200 sensor.

The robotic arm is set to the ready position to begin the sorting procedure. When a colour block is placed within 1cm of the TCS3200 colour sensor, it receives the frequency signal and causes four servos to move to the preset position based on the detected colour. This communication and control method is aided by the ESP 32 microcontroller.

In short, the prototype is made up of an articulated robotic arm that is controlled by an ESP32. Colour blocks are used in the item placement method, and the TCS3200 colour sensor accurately identifies the colours of the blocks. The robot arm can be moved manually through the slider button in the Blynk application. The robot arm can move from a minimum angle of 0 up to a maximum angle of 180 degrees.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The growing demand for automated object sorting systems in a variety of industries has resulted in the development of novel technologies that can improve accuracy and efficiency. The purpose of this literature study is to investigate existing research and technologies relevant to the creation of an IoT-integrated automatic object sorter employing a robot arm and microcontroller. The project will use IoT sensors to provide real-time monitoring and control, which will improve the accuracy and efficiency of the sorting process.

2.2 History of Robotic

The history of robotics is an engrossing story that spans decades, highlighting humanity's drive to construct machines in its own image. Each step in this journey, from ancient automata to sophisticated robots of today, has left an everlasting effect on our civilization. The purpose of this paper is to provide a succinct review of the important milestones and transformative breakthroughs in robotics.

Robotics may be traced back to ancient civilizations, where inventive mechanical devices such as the water clock and mechanical birds hinted at the possibility of automated machinery. However, it was not until the Industrial Revolution that robotics actually took shape. Inventors like Jacques de Vaucanson and George Devol established the groundwork for industrial automation, culminating in the Unimate robot's creation in 1961. This digitally programmable robot transformed production processes and set the way for today's robots.

The introduction of artificial intelligence in the mid-twentieth century opened up new possibilities for robots. Robots gained the ability to comprehend and interact with their surroundings when better algorithms and sensors were developed. This resulted in the creation of self-driving robots capable of executing difficult activities such as space exploration and surgical treatments. A substantial effort has also been on developing humanoid robots that imitate human form and behaviour. ASIMO and Sophia, for example, have pushed the frontiers of what is feasible, demonstrating human-like gestures and enabling improvements in human-robot interaction.

As robots grow more interwoven into all sectors of society, ethical concerns have risen to the fore. The course of future growth is being shaped by discussions about employment displacement, privacy, and the societal implications of robotics. The discipline of robotics is still evolving, with continuing research focusing on topics like as soft robotics, swarm robotics, and cognitive capabilities. Robotics has enormous potential in the future to further alter industries, improve quality of life, and open new frontiers of discovery.

The history of robotics is a monument to human creativity and the persistent quest of innovation. From humble beginnings to the complex and adaptable robots we have today, each chapter in this saga has contributed to our understanding of automation and the possibilities it contains. As we traverse ethical challenges and embrace new technological boundaries, the future of robots holds fascinating possibilities that will profoundly impact our world [3].

2.3 Automated Object Sorting Systems

Due to its capacity to boost productivity and eliminate human error, automated object sorting systems have attracted substantial interest in areas such as manufacturing, logistics, and recycling. The fast growth of industries has created a demand for various automation robots that can improve the efficiency of the operation process. [4]. Traditional sorting systems frequently necessitate manual intervention and do not provide real-time monitoring. However, as IoT and robotics technology have improved, automated sorting systems have gotten more sophisticated and efficient. The robot also gets the work done with minimal error and in less time which in turn increases the profitability of the operation.

Automated object sorting systems are meant to efficiently and accurately categorise or sort diverse things based on predetermined criteria. To detect, inspect, and sort things in a high-speed manufacturing environment, these systems use a combination of technologies such as machine vision, robots, sensors, and artificial intelligence.

2.3.1 Robot Arm in Object Sorting

Robot arms are critical components of automated object sorting systems because they provide the dexterity and precision required to handle things. They can be designed to do sophisticated sorting tasks based on predefined parameters such as size, shape, colour, or weight. Robot arms are versatile and adaptable, making them appropriate for a wide range of sorting applications.

A robotic arm is a programmed device that use digital technology to carry out particular tasks in a variety of industries, including manufacturing, fabrication, postal services, and home automation [5][6]. According to its degree of freedom (DOF) [7], a robotic arm can be designed in a variety of ways depending on the type of joints utilised, including cartesian, cylindrical, spherical, articulated, and Selective Compliance Assembly Robotic Arm (SCARA).

The range, operational capability, and reach of robot arms determine their type. Pick and place labour, charting, and arc welding are all done with Cartesian robots. Its range is primarily two-dimensional. Cylindrical robots are likewise employed for the aforementioned task categories, but because they function in a cylindrical coordinate system, they can do the activities more precisely and accurately, and they also have a broader reaching range. The polar coordinate system is used by the spherical robot. SCARA robots are mostly utilised for pick and place tasks. To give flexibility in a plane, it must parallel rotary joints. It is then frequently integrated with additional processes to achieve three-dimensional reach. Three rotary joints are used by an articulated robot. In the mobile platform that handles cockpit light simulators, parallel robots are used. It is a robot with concurrent prism shaped or rotational joints in its arms. An anthropomorphic robot is one that looks like a human hand and has separate fingers and thumbs.

Workers have been required to practise social distance at work since the onset of the pandemic Covid-19 to limit the chance of becoming infected by one another [8]. In this context, a robotic arm with functionalities similar to a human arm is more important than ever to offer more convenient access. This is true for persons who work in post offices, food processing plants, and other businesses where there are a lot of objects to sort [9][10].

FIGURE 2-1 Example of robotic arm [11]

2.3.2 Robotic Arm Grippers

Robot manipulators are now one of the most important topics of interest for scientists, engineers, and even doctors, not only as a unique and emerging study subject, but also as a usable and helpful instrument for a variety of reasons. Manipulation and grasping are defined differently depending on the situation and application. In general, mechanical manipulation is defined as the act of applying force or torque to an item to cause motion or deformation, whereas grasping is the act of holding an object. Manipulators, in general, have a variety of applications. Gripping is a frequent process performed by manipulators. Each manipulator requires a gripper, which is installed on the manipulator's end effector, to execute a gripping task. Manipulation speed, item form, weight, and other considerations all play a role in gripper selection. Some smart grippers, on the other hand, are intended for universal use and varied object forms[12]. As an illustration, in [13] a versatile gripper is proposed for gripping objects of various geometries.

There are some academic reviews on various types of grippers. Birglen et al. offered an overview of industrial grippers and a comparison of several varieties [14]. In [14] some parameters that are considered while comparing industrial robots are the stroke, force, weight, power, and finger length of industrial grippers. In [15] present a review on composite grippers. In [16] and [17] a detailed review of soft robot grippers are presented. Agnus et al. in [18] provide an overview on recently-developed micro grippers.

Another sort of categorisation is considered in terms of actuation. The actuation method for each gripper is determined by the characteristics of the object [19].

2.3.2.1 Vacuum Gripper

The vacuum gripper is made up of a rubber or foam suction portion that holds the object in place [19]. The advantage of vacuum grippers is that they are highly flexible while giving a firm hold on an object. This form of gripper is preferred in applications where contamination may be a problem because air is clean and may be delivered through tubes and hose.

FIGURE 2-2 Example of vacuum gripper [20]

2.3.2.2 Pneumatic Gripper

A bang-bang actuator is a pneumatic robot gripper. The advantages of pneumatic grippers are their small size and light weight [19]. In terms of pollution, they have the same advantage as vacuum grippers.

FIGURE 2-3 Example of pneumatic gripper [21]

2.3.2.3 Hydraulic Gripper

Hydraulic grippers acquire strength thanks to hydraulic pumps. When compared to other types of grippers, these have a greater capacity to exert a significant level of force. The force is generated by the pressure increase in the actuator's several chambers. The downside of hydraulic grippers is that they must be maintained on a regular basis [19]. The advantage of hydraulic grippers is that they can hold an object even when the pressure supply is cut off, i.e., there is no need to supply energy when the gripper is in still mode, reducing the amount of energy required in applications where an object must be held for an extended period of time without movement.

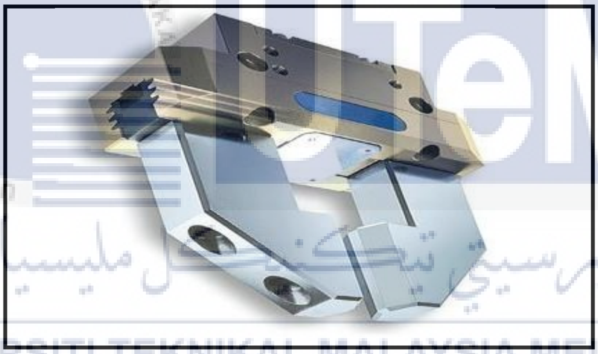

FIGURE 2-4 Example of hydraulic gripper [22]

2.3.2.4 Servo-Electric Gripper

The servo-electric gripper is extremely adaptable. As a result, it is not limited to dealing with a certain item. The electronic motor that controls the fingers or jaws is the most significant component of the servo-electric gripper. The key advantages of these grippers are their ease of control, minimal maintenance costs, and high adaptability [19].

FIGURE 2-5 Example of servo-electric gripper [23]

2.3.2.5 Claw Gripper

The claw gripper works by using a mechanical mechanism to open and close, allowing the robot to grasp and release things. The gripper is made up of two or more moveable fingers or jaws that are either pneumatically, hydraulically, or electrically operated. These fingers or jaws move in unison to securely grab the object being grasped.

In robotic applications, the claw gripper has various advantages. For starters, it is versatile in that it can accommodate a wide range of object sizes and shapes, allowing for effective handling in a variety of jobs. Second, its mechanical design provides dependability by offering a tight grasp and reducing the possibility of things dropping or losing control. Finally, the claw gripper is inexpensive, with a simple design and simple programming, giving it an accessible and affordable solution for incorporation into robotic systems. These benefits add up to increased production and efficiency in a variety of businesses that use robotic automation [24].

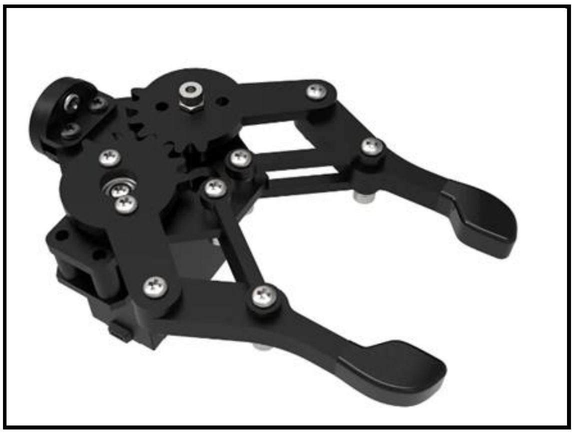

FIGURE 2-6 Example of claw gripper [25]

2.4 Colour Sensor

2.4.1 Introduction to Colour Sensor

The colour sensor senses the surface's colour, which is commonly in the RGB scale. Colour is created by the interaction of a light source, an object, and an observer. Colour sensors have a wide range of uses, including environmental monitoring, product selection, and sorting. Colour sensors are typically employed for two purposes: genuine colour recognition and colour mark detection. True colour recognition sensors must be able to "see" different colours or discern between shades of a specific colour. They can be used in both sorting and matching modes. There are two methods for measuring the colours of substances. The simplest method is to utilise a color-changing light source and a sensor that monitors light intensity.

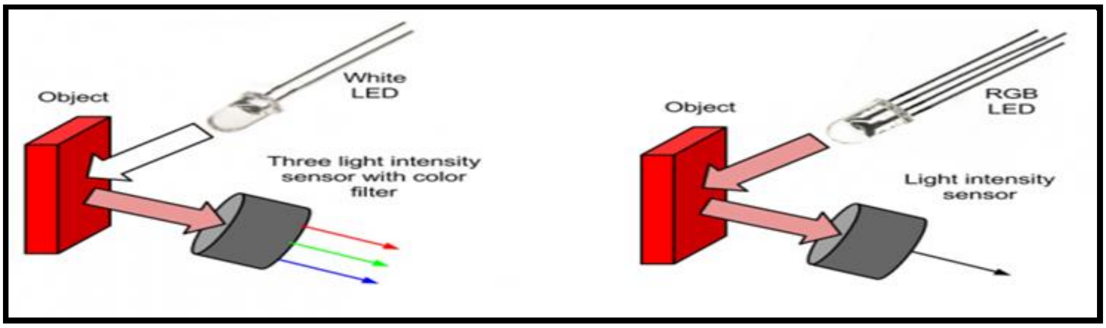

FIGURE 2-7 How a color sensor works

2.4.2 TCS3200 Colour Sensor

The system is aided by a TCS3200 colour sensor[26][27]. The use of this sensor may be a way to assist a corporation in increasing its productivity [28]. The robot will separate objects depending on the colour that has been modified to identify commodities that can be processed using this device.

Problems are reduced after using the TCS3200 sensor with pre-registered colours in the controller (red, yellow, and blue) for distinguishing items depending on colour that has been modified. This device causes the servo motor in the robotic arm to transport things to the container based on their colour.

The TCS3200 sensor is an Integrated Circuit that can transform the colour of light into a frequency value and can store up to 25 colour data points [29]. The photodetector of the TCS3200 module features red, green, blue, and clear colour filters. The filters are distributed to each of the 8x8 array of photodiodes. This module generates a square wave oscillator with a frequency equal to the colour observed. This tool's two major components are a photodiode and a current to frequency converter (ADC)[30]. TCS3200 colour sensor is essentially a light sensor with a light filter for basic colours such as RGB (Red-Green-Blue) [31].

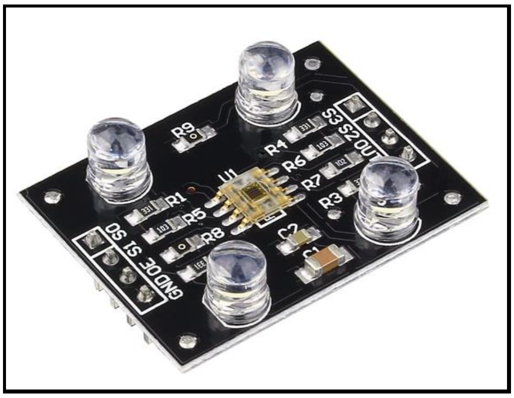

FIGURE 2-8 TCS3200 Colour sensor [32]

2.4.3 TCS3400 Colour Sensor

To detect light in multiple colour channels, colour sensors, especially RGB colour sensors, often employ an array of photodiodes or photodiode sensors. The intensity of light is converted into electrical impulses that may be detected and analysed by these sensors. In the case of the TCS3400 (if it operates on a similar basis), photodiodes sensitive to red, green, blue, and potentially clear light are most likely included. The intensity of light in their respective colour ranges is detected by these photodiodes and converted into electrical impulses. To improve the accuracy and precision of colour identification, the TCS3400 may include extra components like as filters, amplifiers, and analog-to-digital converters (ADCs) [33].

The TCS3400 and TCS3200 colour sensor modules have major variations. In comparison to the TCS3200, the TCS3400 has superior sensing capabilities, including greater colour accuracy, sensitivity, and a broader dynamic range. Furthermore, the TCS3400 often has digital output, which simplifies integration with digital devices and eliminates the requirement for analog-to-digital conversion. It may also incorporate extra features like as integrated infrared blocking filters and programmable settings, allowing for increased versatility and customization. Understanding these distinctions aids in selecting the best sensor for certain application requirements.

The TCS3400 colour sensor has a number of advantages. For starters, it enables accurate and dependable colour recognition, allowing for precise colour analysis and identification. Second, its small size and ease of integration make it highly versatile and applicable to a wide range of sectors, including automation, quality control, and printing. Finally, because subjective judgements are eliminated, the sensor delivers objective colour measurements, ensuring consistency and increasing overall efficiency in color-related activities.

FIGURE 2-9 TCS3400 Colour Sensor [34]

2.4.4 AS73211 Colour Sensor

The AS73211 colour sensor works by catching light at multiple wavelengths to detect the colour of an object. It employs a photodiode array to measure light intensity in the red, green, and blue (RGB) channels. These RGB data are subsequently transformed into XYZ colour coordinates, which represent the perceived colour.

The AS73211 sensor employs complex algorithms and calibration processes to provide accurate colour detection. It adapts for ambient light conditions and reduces the impact of varied light sources, improving colour measuring precision and reliability.

Through the I2C interface, the sensor communicates with a microcontroller or host device, allowing for easy integration and control. It sends the collected colour data to the linked system for processing and analysis.

The AS73211 colour sensor is used in a variety of applications, including colour detection, quality control, and image processing. Its ability to measure colours properly makes it a crucial tool in businesses that rely on precise colour analysis and uniformity.

To summarise, the AS73211 colour sensor captures light in RGB channels, transforms it to XYZ colour coordinates, and transmits colour data over the I2C interface. It guarantees precise colour identification and seamless integration into various systems thanks to innovative algorithms and calibration processes. The features of this sensor make it well-suited for applications needing consistent and precise colour measurements. [35]

The AS73211 colour sensor has a number of advantages. For starters, it has great colour detection accuracy and reliability, ensuring precise readings across a wide range of objects and lighting circumstances. Second, its superior calibration processes reduce the influence of ambient light, resulting in consistent and reliable colour readings. Finally, the AS73211 colour sensor has an easy-to-use I2C interface that allows for smooth interaction with microcontrollers and host devices, simplifying implementation. These benefits add together to make the AS73211 colour sensor a powerful tool for applications requiring accurate colour detection and analysis, such as improving quality control systems, image processing applications, and other color-dependent sectors.

FIGURE 2-10 AS73211 Colour Sensor [36]

2.5 Servo Motor

2.5.1 Introduction to Servo Motor

A servo motor is an electromechanical device that translates electrical inputs into controlled mechanical motion. It is widely utilised in robotics, industrial automation, and aerospace applications that demand precise positioning. A servo motor is made up of three components: a motor, a feedback sensor, and a control circuit. The control circuit compares the desired position to the actual position provided by the feedback sensor and changes the rotation of the motor accordingly. The servo motor can retain a precise position or follow a set trajectory with excellent accuracy and responsiveness thanks to this closed-loop control system. The servo motor is a crucial component in modern automation systems because to its adaptability and dependability.

2.5.2 MG90S

MG90S motor for movement purposes. Four MG90S servos were employed as the actuator for position. These motors were put at each joint to correctly arrange things in the desired position. The robot arm is expected to have a smooth movement and high accuracy in detecting colours for scanned objects [27] [37] [38].

FIGURE 2-11 MG90S Servo Motor [39]

2.5.3 SG90

The SG90 servo motor is a small and inexpensive electromechanical device that is commonly utilised in hobbyist projects and small-scale applications. It provides fine angular movement control, low power consumption, and moderate torque output. Its tiny design makes it popular among robotics and automation enthusiasts for a variety of robotic and automation projects.

Small and light, but with a high output power. The servo can rotate roughly 180 degrees (90 degrees in each direction) and functions similarly to the regular kind but in a smaller size. To control these servos, you can use any servo code, hardware, or library. It's ideal for beginners who want to make things move without having to create a motor controller with feedback and a gear box, especially since it can fit in small spaces [40].

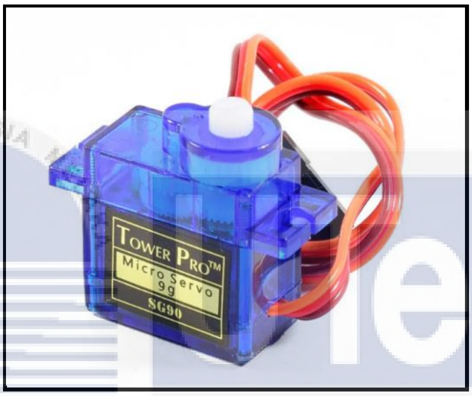

FIGURE 2-12 SG90 Servo Motor [41]

2.6 Microcontroller

2.6.1 Introduction to Microcontroller

A microcontroller is a circuit board incorporated within each component that may conduct a certain task on a regular basis. A CPU, memory units, and input-output interfaces are all included, as are ADC, PWM, and various control and communication modules.

The microcontroller contains memory units with specialised functions linked to the arithmetic-logical unit (ALU), certain registers, a processor control unit, and a processor core. There are two kinds of memories: permanent memories and temporary memories.

Random access memory (RAM) stores the information required by the processor during its operation, but ROM, PROM, EPROM, and EEPROM memories do not change their contents and retain information such as the command set, programme, and programme data as long as they are not reprogrammed. The microcontroller's input and output sections are specific recording sections that allow it to receive and transfer data to external units [42]. There are various types of microcontrollers that are often used. The most popular processors are Intel, AVR, ARM, and PIC.

2.6.2 Intel 8051 Microcontroller

The Intel 8051 microprocessor series was introduced in 1981 as an 8-bit microcontroller series. This is now one of the most popular microcontroller families on the market. This microcontroller is also referred to as a "machine on a chip" since it has 128 bytes of RAM, 4Kbytes of ROM, 2 Timers, 1 Serial port, and 4 ports all on a single chip.

Furthermore, because the 8051 is an 8-bit processor, it can only handle 8 bits of data at a time. If the data is more than 8 bits, it must be broken into portions so that the CPU can handle it efficiently. Although the quantity of ROM bytes can be increased to 64K, most manufacturers only provide 4K bytes. Because of its simplicity of integration into projects, the 8051 has been used in a wide range of products [43].

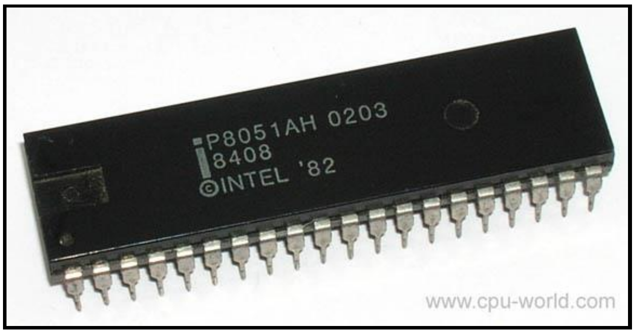

FIGURE 2-13 Intel 8051 Microcontroller [44]

2.6.3 Pic Microcontroller

Microchip launched the PIC microcontroller in 1993, despite the fact that General Instruments invented the initial chip design in 1985. PIC microcontrollers are intended for use in embedded system design to enable simple programming and interfacing. Although Microchip did introduce some 16-bit and 32-bit PIC microcontrollers, the majority of PIC microcontrollers that hit the market are 8-bit microcontrollers.

PIC microcontrollers are based on the Harvard architecture, which separates the programme and data buses. Early versions of PIC microcontrollers used EPROM to store programme instructions, but since 2002, they have used flash memory to allow for better erasing and saving of the code.

PIC microcontrollers have proven to be popular among enthusiasts, students, and professionals due to their simple architecture and ease of use. Some of the most popular PIC microcontrollers with minimal functionality were the PIC16F84 and PIC16F877. The PIC18F family can be used in applications that require more peripherals, greater performance, or memory [45].

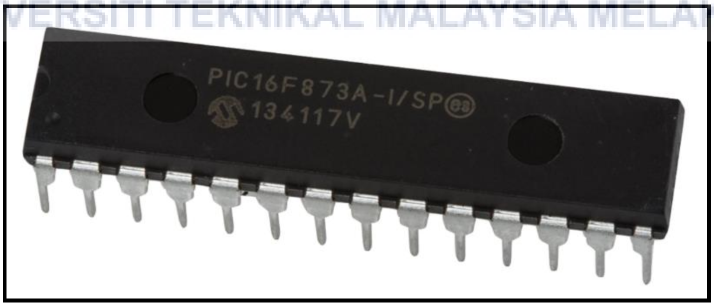

FIGURE 2-14 Pic Microcontroller [46]

2.6.4 Arm Microcontroller

An ARM processor is a CPU designed by Advanced RISC Machines that is based on the RISC architecture (reduced instruction set computer) (ARM). ARM manufactures 32-

bit and 64-bit RISC multi-core CPUs. RISC processors are designed to operate at a faster rate by executing a smaller number of different types of computer instructions. This enables them to do millions of instructions per second (MIPS). RISC computers achieve excellent results at a fraction of the power consumption of CISC (complex instruction set computing) approaches by deleting unneeded instructions and optimising pathways.

ARM processors can be found in a variety of electronic devices, including smartphones, PCs, video players, and other mobile devices like wearable technologies. They require fewer transistors since they have a smaller instruction set, allowing for a smaller integrated circuitry die size (IC). Because of their small size and low power consumption, ARM processors are well suited for increasingly small applications [43].

FIGURE 2-15 Arm Microcontroller [47]

2.6.5 AVR Microcontroller

In 1996, Atmel Corporation designed the AVR microprocessor. Alf-Egil Bogen and Vegard Wollan devised the AVR's structural architecture. The AVR microcontroller, also known as the Advanced Virtual RISC, was named after its creators, Alf-Egil Bogen and Vegard Wollan. The AT90S8515 was the first AVR-based microcontroller, while the AT90S1200 was the first commercial microcontroller in 1997.

AVR microcontrollers are classified into three types: TinyAVR, MegaAVR, and XmegaAVR. TinyAVR has the most memory and is the smallest in size, making it excellent for simple applications. MegaAVR is the next most prevalent, with a large amount of memory (up to 256 KB), a wider range of integrated peripherals, and is suitable for simple to complex applications. Finally, the XmegaAVR is used in commercial applications that require a huge amount of programme memory and high speed [43].

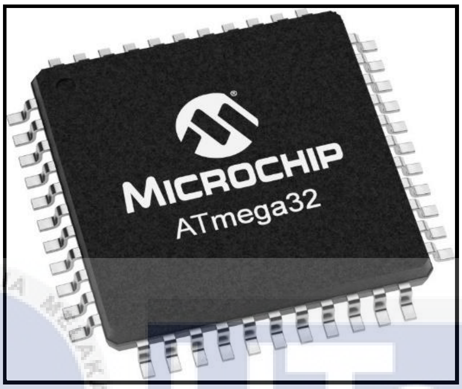

FIGURE 2-16 AVR Microcontroller [48]

2.6.6 Arduino

Arduino is a hardware/software programming platform based on Atmel (AVR) microcontrollers that is free and open source. Open source circuit schematics and software source code used in designs are available for download and can be updated by enthusiasts. Because of their analogue and digital inputs and outputs, Arduino development boards are ideal for artists, designers, and electrical hobbyists who want to build a gadget without knowing much about digital design. Individual leads or single in line (SIL) connections can be placed into rows of female connectors on the Arduino board to provide input and output signals.

Most Arduino development boards have at least 9 digital pins that can be used as input/output channels. PWM (Pulse Width Modulation) outputs can be configured on certain of them. A PWM signal is a square wave with a changeable pulse width. It was used in robotics and remote control applications to control the speed and position of motors and servos. Then there are four analogue input channels and at least one serial port for uploading code to the Arduino.

The Arduino family includes the Arduino Nano, Arduino Micro, Arduino Due, Arduino Mega (R3) Board, Arduino Leonardo Board, LilyPad Arduino Board, and the Arduino Uno (R3) [49].

2.6.6.1 Arduino Nano

Gravitech created the Arduino Nano, a small and breadboard-compatible microcontroller board. Both the ATmega328-based Nano 3.0 and the ATmega168-based Nano 2.x are available. The Nano provides comparable capabilities, but in a different form factor, to the Arduino Duemilanove. The Nano does not have a DC power connection, however a Mini-B USB cable can be used to power and programme it. Its portability and convenience are improved by this feature. The Nano was created and is produced by Gravitech, a seasoned manufacturer of Arduino-compatible goods. The board can be seamlessly integrated with current projects thanks to its compatibility with the Arduino software and libraries. The Arduino Nano is incredibly adaptable and suited for many programming and electronics applications, especially where space is at a premium. Its compact size, interoperability with breadboards, and USB-powered operation contribute to its appeal [50].

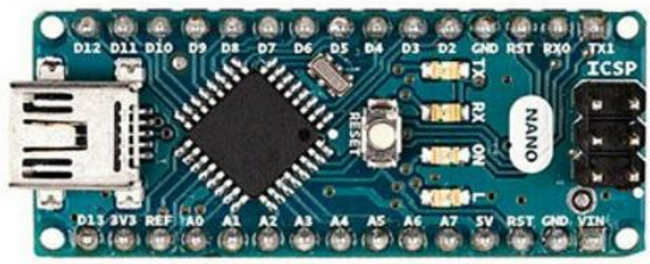

FIGURE 2-17 Arduino Nano [51]

2.6.6.2 Arduino Micro

The ATmega32u4 microprocessor serves as the foundation of the Arduino Micro, a microcontroller board created in collaboration with Adafruit. There are 20 digital input/output pins available, including 12 analogue inputs and 7 PWM outputs. It has all the functionality required for microcontroller compatibility, including a reset button, ICSP header, and 16 MHz crystal oscillator. The Micro can be placed on a breadboard with ease thanks to its small form factor. Notably, it does not require a separate processor because it uses the built-in USB connection of the ATmega32u4. Due to this, a connected computer can recognise the Micro as a virtual serial/COM port, mouse, and keyboard. Since it can simulate input devices, this capability broadens its possible applications. Simply plug in the Micro using a micro USB connection to start using it. On the official "getting started" page, more information about its behaviour and features may be found [52].

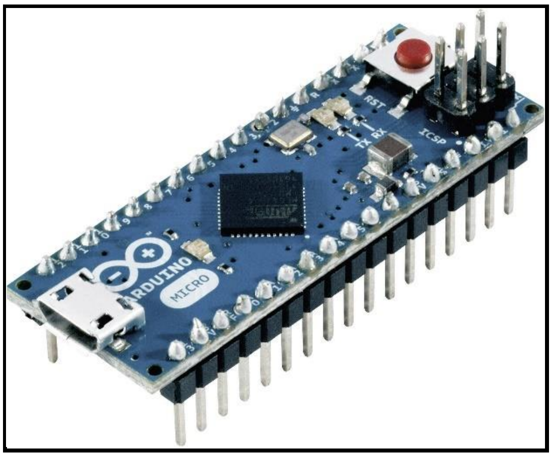

FIGURE 2-18 Arduino Micro [53]

2.6.6.3 Arduino Mega (R3) Board

A microcontroller board with many features, the Arduino Mega 2560 is based on the ATmega2560. The device has 4 UARTs, 16 analogue inputs, and 54 digital input/output pins, 14 of which are PWM outputs. It has everything required to support the microcontroller, including a 16 MHz crystal oscillator, USB connection, power jack, ICSP header, and reset button. Battery, an AC-to-DC adapter, or USB can all be used to power the Mega 2560. One of its main benefits is compatibility with the majority of Duemilanove or Diecimila shields, allowing for the expansion of its functionality through a variety of already available add-on boards. This qualifies it for intricate projects needing several sensors, actuators, and communication channels. Due to its wide range of I/O choices and suitability for sophisticated applications, the Mega 2560 is a flexible alternative for demanding applications [54].

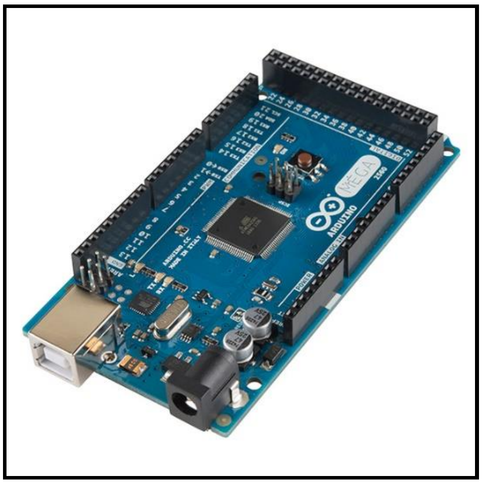

FIGURE 2-19 Arduino Mega (R3) Board [55]

2.6.6.4 Arduino Uno (R3)

The microcontroller Arduino UNO (ATMEGA328P-Arduino IDE) is utilised in this project. The robot arm's movements can be controlled by the ATmega328P microprocessor[12]. You may transmit exact commands to control the arm's mobility by linking the microcontroller with the actuators and motors on the robot arm, allowing it to pick up and position objects correctly.

To ensure efficient and precise object sorting, an algorithm using the ATmega328P microcontroller must be implemented. The algorithm will evaluate sensor input, make choices based on established criteria (e.g., colour, size), and provide control signals for the robot arm. The Arduino IDE is a user-friendly platform for programming the microcontroller with a simplified version of the C++ programming language.

FIGURE 2-20 Arduino Uno (R3) [56]

2.6.7 ESP 8266

The ESP8266 is a low-cost Wi-Fi microchip with build in TCP/IP networking software and microcontroller capability, produced by Espressif Systems in Shanghai, China.

The chip was popularized in the English-speaking maker community in August 2014 via the ESP-01 module, made by a third-party manufacturer Ai-Thinker. This small module allows microcontrollers to connect to a Wi-Fi network and make simple TCP/IP connections using Hayes-style commands. However, at first, there was almost no English-language documentation on the chip and the commands it accepted.

The very low price and the fact that there were very few external components on the module, which suggested that it could eventually be very inexpensive in volume, attracted many hackers to explore the module, the chip and the software on it, as well as to translate the Chinese documentation [57].

There are open-source prototyping board plans available for the Node-MCU firmware. "Node-MCU" (miniature control unit) combines the terms "node" and "MCU" in its name. The designs for the prototyping board and firmware are both open-source. The prearranging language Lua is used by the firmware. The Lua programming language is used by firmware developers to create embedded applications for microcontrollers, including those based on the ESP-8266 chipset. Lua is often used to create scripts that can be run on the ESP-8266 platform to control devices or implement custom functionality. The firmware is based on the Espressif Non-OS SDK for ESP-8266 and is dependent on the eLua project.

A circuit board acting as a double in-line package (DIP) coordinates a USB regulator with a more modest surface-mounted board containing the MCU and receiving wires serve as the typical prototyping apparatus. The startegy initially depended on the ESP-12 module of the ESP-8266, a Wi-Fi SoC with a Tensilica Xtensa LX106 core is widely used in Internet of Things application. So it is simpler to utilize Node-MCU for applications that need fewer GPIO pins and associate with a Wi-Fi network [58].

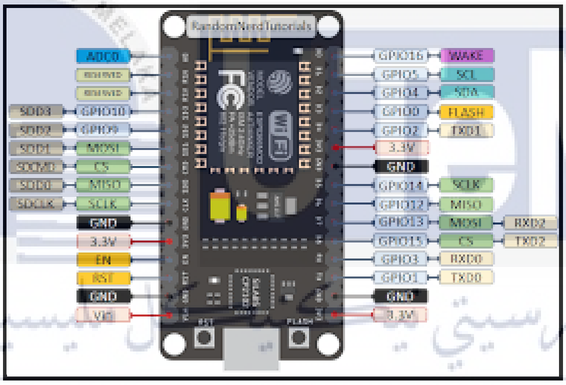

FIGURE 2-21 Pin Configuration for ESP 8266 [59]

2.6.8 ESP 32

The ESP32 is powerful SoC (System on Chip) microcontroller with integrated Wi-Fi 802.11 b/g/n, dual mood Bluetooth version 4.2 and variety of peripherals. It is an advanced successor of the 8266 chip primarily in the implementation of two cores clocked in different version up to240 MHz. Compared to its predecessor, except these features, it also extends the number of GPIO pins from 17 to 36, the number of PWM channels per 16 and is equipped with 4MB of flash memory.

The ESP32 chip has been developed by the Espressif Systems company, which currently offers several ESP32 versions of the SoC in the form of ESP32 Developer Kit, the ESP32 Wrover Kit, which also includes an SD card and 3.2 " LCD display and last but not least the ESP32 Azure IoT kit with USB Bridge and other built-in sensors. In addition to Espressif Systems, other producers are devoted to these chips - SparkFun with ESP32 Thing DB, WeMoS with its TTGO, D1, Lolin32 and Lolin D32, Adafruid (with Huzzah32), DF Robot (ESP32 FireBeeatle) and many other manufacturers sometimes offer good and sometimes bad clones [60].

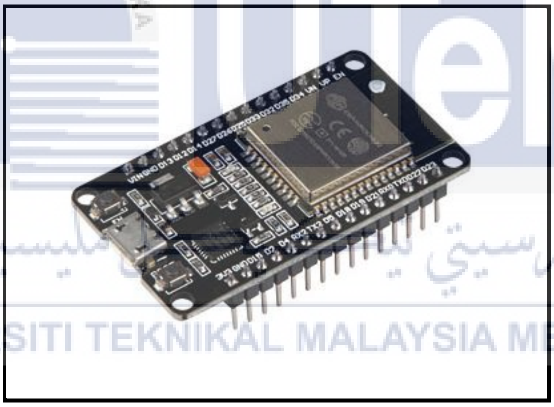

FIGURE 2-22 ESP 32

2.7 Internet of Things (IoT)

2.7.1 Introduction to Internet of Things (IoT)

The Internet of Things (IoT) is a game-changing idea that connects everyday objects and equipment to the internet, allowing them to collect and exchange data. IoT systems are made up of a variety of interconnected devices, sensors, and networks that communicate with one another to allow for seamless data flow and analysis. This connectivity enables the monitoring, automation, and remote control of objects and processes in real time.

IoT applications are numerous and diverse. IoT devices in healthcare can monitor patients' vital signs, allowing for early detection of health issues. IoT sensors in agriculture can optimise irrigation and automate farming activities. IoT technology can improve energy management, traffic control, and waste management systems in smart cities. The growth of IoT, however, raises issues about data privacy and security. With so many networked devices, protecting sensitive data becomes critical. Overall, this journal's introduction to IoT provides a look into this technology's disruptive potential. IoT gives up new opportunities for efficiency, convenience, and creativity across multiple domains by enabling the connectivity of devices and utilising the power of data [61].

An IoT ecosystem is made up of web-enabled smart devices that acquire, transmit, and act on data from their surroundings using embedded systems such as CPUs, sensors, and communication gear. Sensor data from IoT devices can be shared with an IoT gateway or other edge node, which can subsequently be sent to the cloud for analysis or processed locally. These gadgets will occasionally communicate with one another and act on the data they receive. Humans may communicate with devices to set them up, give them instructions, or access data, but electronics do the majority of the work on their own. The connection, networking, and communication protocols used by these web-enabled devices are essentially governed by the installed Internet of things. IoT may also leverage artificial intelligence (AI) and machine learning to make data collection operations simpler and more dynamic [62].

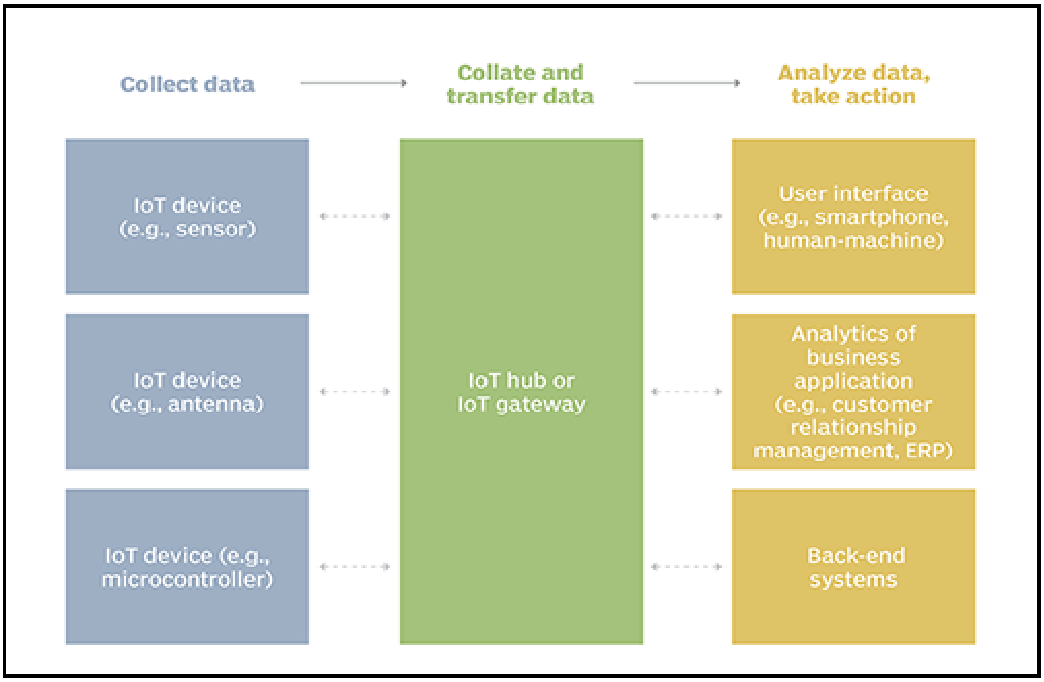

FIGURE 2-23 Example of IoT System

2.7.2 History of Internet of Things (IoT)

Kevin Ashton, co-founder of the Auto-ID Centre at the Massachusetts Institute of Technology (MIT), originally mentioned the internet of things in a presentation to Procter & Gamble (P&G) in 1999. To bring radio frequency identification (RFID) to the attention of P&G's top management, Ashton dubbed his presentation "Internet of Things" to embrace the cool new trend of 1999: the internet. When Things Start to Think, a book by MIT professor Neil Gershenfeld, also released in 1999. It didn't use the exact word, but it conveyed a clear picture of where the Internet of Things was headed.

The Internet of Things is a hybrid of wireless technologies, microelectromechanical systems (MEMSes), micro services, and the internet. Convergence has aided in breaking down barriers between operational and information technology, allowing for the examination of unstructured machine-generated data for insights that may be used to drive improvements.

Although Ashton was the first to explain the internet of things, the concept of linked devices has existed since the 1970s, under the terms embedded internet and pervasive computer. In the early 1980s, the first internet appliance was a Coke machine at Carnegie Mellon University. Programmers could use the web to check the status of the machine and see whether there was a cold drink waiting for them if they decided to go to the machine.

IoT emerged from M2M communication, which involves devices communicating with one another via a network without the need for human intervention. M2M refers to the process of connecting a device to the cloud, administering it, and collecting data. The Internet of Things (IoT) is a sensor network of billions of smart devices that connects people, systems, and other applications to gather and exchange data, bringing M2M to a new level. M2M serves as the foundation for IoT by providing connectivity.

The Internet of Things is also a natural extension of supervisory control and data acquisition (SCADA), a type of process control software that collects real-time data from remote locations to regulate equipment and conditions. SCADA systems are made up of both hardware and software. The hardware collects and transmits data to a computer running SCADA software, which processes and displays it in real time. SCADA has progressed to the point where late-generation SCADA systems are now first-generation IoT systems.The Internet of Things ecosystem, on the other hand, did not take off until the middle of 2010, when China's government declared IoT to be a strategic priority in its five-year plan [62].

2.7.3 IoT in Object Sorting

The Internet of Things (IoT) has fundamentally revolutionised numerous industries, including object sorting. The Internet of Things (IoT) enables the integration of sensors, actuators, and connections, allowing for real-time data collection, analysis, and control. The introduction of IoT technology into object sorting systems can significantly improve the accuracy and efficiency of the sorting process.

The Internet of Things (IoT) plays a critical role in improving object sorting systems by simplifying connectivity and data exchange between objects, sensors, and the sorting system itself. As part of an IoT application, all data from the arm will be wirelessly communicated and remotely monitored utilising the ThingSpeak platform [63][64].

2.7.4 Internet of Things Software and Platforms

Industry demand for IoT devices is increasing daily. More smart devices were produced as a result. In order to support the cutting-edge inventions around the world, additional platforms and applications were required as more gadgets were being developed and will be made.

Many different platforms currently support Internet of Things devices. However, some people are the most competitive. The most popular of the top five (5) applications is Blynk, followed by Particle, AWS IoT, and Google Cloud IoT Core.

2.7.4.1 Particle

Particle is an IoT device platform that simplifies the process of connecting devices to the internet. It provides developers with an easy way to design, connect, and manage their linked systems and applications. With Particle's platform, you can create connected systems like smart homes. All Particle Devices come with free access to the Particle Cloud, which acts as a bridge between your devices and the internet. The platform offers features like over-the-air firmware updates, a REST API, and firmware generation supported by online and local IDEs, making it ideal for creating IoT projects.

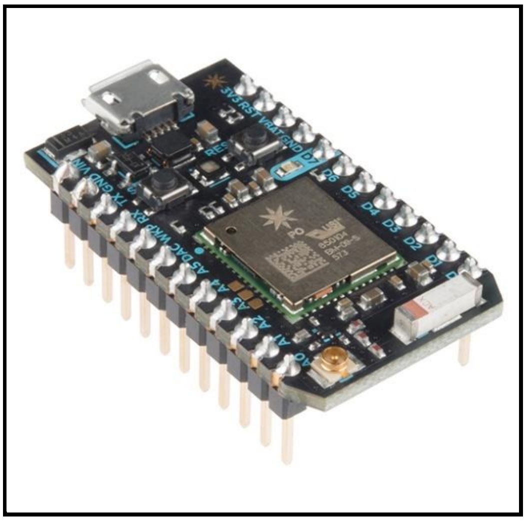

FIGURE 2-24 Particle photon (Wifi-) Board [65]

The Particle Photon is a compact Wi-Fi development kit with a Broadcom Wi-Fi chip and a powerful ARM Cortex M3 microprocessor, while the Particle Electron is a cellular development kit with a Particle SIM card and data plan for low-bandwidth applications. These boards enable the creation of linked projects and applications [66].

FIGURE 2-25 Particle Electron (Cellular) Board [67]

2.7.4.2 AWS IoT

AWS IoT is a sophisticated Internet of Things platform supplied by Amazon Web Services that allows users to connect their IoT devices to the cloud without the need for server installations or maintenance. It is capable of securely processing and directing large numbers of devices and communications to numerous AWS destinations and other devices. Amazon S3, Amazon Kinesis, AWS Lambda, AWS CloudTrail, Amazon SageMaker, Amazon QuickSight, Amazon DynamoDB, Amazon CloudWatch, and Alexa Voice Service are just a few of the Amazon services that AWS IoT Core integrates with. These services can be used to create IoT applications that gather, process, analyse, and act on data created by connected devices without the need for sophisticated procedures. Developers can use AWS IoT Core to leverage the power of Amazon's entire portfolio of services to create unique and scalable IoT solutions [68].

2.7.4.3 Google Cloud IoT Core

Google Cloud IoT Core is a cloud-based IoT platform designed for businesses of all sizes. It provides a comprehensive suite of tools for managing, analyzing, storing, and processing data in both on-premise and cloud environments. Unlike some other platforms, Google Cloud IoT does not offer a free trial and is not free to use, which may present challenges for smaller projects. However, it offers the ability to connect to a wide range of devices and provides a centralized location for communication via MQTT or HTTP protocols. Google Cloud IoT Core prioritizes security by encrypting client devices when connecting to different networks, enabling efficient and secure two-way communication. One drawback is that user data files are stored remotely, which means users have limited direct control over their data. Additionally, the platform may initially have a steep learning curve but becomes easier with more usage over time.

2.7.4.4 Blynk

Blynk IoT is a software platform that enables easy prototyping, deployment, and management of connected devices, from small-scale projects to large commercial products. It pioneered a no-code approach to IoT app development and is renowned for its excellent mobile app editor. With a user base of over 500,000 developers and corporate clients across 136 countries, Blynk finds applications in various industries such as Smart Home, Agriculture, HVAC, and Asset Tracking. While the full version requires purchase, Blynk offers a functional free version with limited features. It excels in hardware management and is beginner-friendly, fostering experimentation and learning in designing IoT products. However, occasional hardware issues and the limitation of connecting to only one device at a time can pose challenges for multi-user monitoring or operation without modifying the code.

2.8 Literature Review Matrix

Title	Author	Method/Solution
Story of Robots	J. Takeno	J. Takeno dives into the extraordinary evolution of robots and their impact on civilization in "Story of Robots." The author follows robotics from its humble beginnings as mechanical contraptions to its current developments in artificial intelligence. Takeno investigates the various applications of robots, such as industrial automation, healthcare aid, and hostile environment exploration. The journal

		emphasises significant advances in robotics technology, such as machine learning and human-robot interaction, that have eased the incorporation of robots into numerous facets of our life. In addition, the author sheds light on the ethical and social issues raised by the widespread usage of robots. "Story of Robots" is a succinct review of the fascinating world of robotics, spanning their past, current, and potential future contributions to humanity. [3]
Automated Object Identifing and Sorting Robot	D. Saxena, P. S. Vamsi, C. V Eedala, and G. K. K	An investigation into the design and development of a robot capable of autonomously identifying and classifying things is presented. The authors stress the need of efficient and accurate sorting processes in many industries and present a solution based on a robotic system outfitted with advanced object identification capabilities. The article goes over the robot's hardware, which includes sensors, actuators, and a microcontroller. The software implementation, which includes image processing and machine learning methods for object recognition and sorting, is described by the authors. The experimental results show that the automated robot is capable of accurately identifying and

		sorting things. The study demonstrates the technology's potential for speeding object sorting operations in industrial settings. [4]
A Review and Analysis of Automation in the Audiovisual Productions	D. Centellas-yucra	Provides a thorough overview and critique of automation techniques used in audiovisual projects. The author investigates the evolution and impact of automated technology in many stages of audiovisual production, including editing, special effects, and post-production. The article examines the advantages and disadvantages of automation in the sector, such as greater efficiency, cost-effectiveness, and creative potential. The author investigates the use of artificial intelligence, machine learning, and robotics in the automation of various areas of audiovisual productions. The study emphasises automation's potential to alter the industry and offers future research directions to improve automation approaches in audiovisual production processes. [5]
Design and Research of Chromatic Confocal System for Parallel Non-Coaxial	Zhang, Yali Yu, Qing Wang, Chong Zhang, Yaozu Cheng, Fang	A study on the design and investigation of a chromatic confocal system that uses parallel non-coaxial illumination is presented. The scientists use an optical fibre bundle for lighting to improve the imaging capabilities and

Illumination Based on Optical Fiber Bundle	Wang, Yin Lin, Tianliang Liu, Ting Xi, Lin	performance of confocal microscopy systems. They talk about the system's design principles, components, and optical arrangement. The paper also includes experimental data and evaluations of the imaging performance of the system, such as resolution and depth of field. The research shows the feasibility and benefits of the proposed chromatic confocal system with parallel non-coaxial illumination, emphasising its potential applications in biological imaging and microscopy. [6]
Development of a 3DOF Color Sorting based Robotic Arm using MATLAB GUI	Mohanto, Tonusree Talukde, Aparajita Tasneem, Zinat	The design and development of a 3-degree-of-freedom (DOF) robotic arm system for colour sorting is the focus of this course, which employs a MATLAB graphical user interface (GUI). The authors emphasise the importance of colour sorting in numerous applications and present a solution that makes use of a robotic arm with colour sensing capabilities. The article goes into the hardware components, such as the robotic arm, colour sensor, and microcontroller, as well as the software implementation, which is done with MATLAB GUI programming. The authors give experimental findings that demonstrate the created system's accuracy in categorising objects

		based on colour. The study demonstrates the robotic arm system's potential for efficient colour sorting jobs, supported by the user-friendly MATLAB GUI interface. [7]
Robots under COVID-19 Pandemic: A Comprehensive Survey	Shen, Yang Guo, Dejun Long, Fei Mateos, Luis A. Ding, Houzhu Xiu, Zhen Hellman, Randall B. King, Adam Chen, Shixun Zhang, Chengkun Tan, Huan	This journal provides a comprehensive survey of the use of robots during the COVID-19 epidemic. The writers dig into the different functions and applications of robots in pandemic fighting, such as healthcare, disinfection, delivery, surveillance, and social interactions. They examine the various sorts of robots used, including as telepresence robots, drones, and automated disinfection systems, as well as the technology and issues involved with them. The survey emphasises the efficiency of robotic solutions in minimising human interaction, lowering virus spread, and assisting healthcare systems. The authors also discuss the ethical implications and public acceptance of robot deployment during the pandemic. The study sheds light on the many applications of robotics in response to the COVID-19 problem. [8]
Multipurpose Industrial Applications	Yenorkar, Rasika Chaskar, U M	This document provides an overview of several versatile industrial uses. The authors look at a variety of industries where multipurpose

		applications can be useful, such as manufacturing, logistics, healthcare, agriculture, and energy. The article addresses the advantages of utilising multipurpose apps in certain industries, including greater productivity, cost effectiveness, and operational efficiency. The authors use particular examples and case studies to demonstrate the actual application of multipurpose applications in various industries. They also talk about the obstacles and future prospects of these applications, including as technological developments and the need for customization to fit unique industrial requirements. Overall, the study emphasises the importance of multipurpose applications in fostering innovation and increasing efficiency across a wide range of industrial sectors.[9]
Development of robotic arm for color based goods sorter in factory using TCS3200 sensor with a web-based monitoring system	Panie, Gregorio Imanuel Efraim Mutiara, Achmad Benny	The design and implementation of a robotic arm system for sorting goods based on colour in a factory setting is the focus of this course. The authors emphasise the need of fast sorting operations in industrial settings and present a colour detection solution based on the TCS3200 sensor. The article goes into the hardware components, such as the robotic arm,

		TCS3200 sensor, and microcontroller, as well as the software implementation, which makes use of a web-based monitoring system. The authors give experimental data that demonstrate the created system's accuracy and efficacy in sorting commodities based on colour. The study emphasises the robotic arm system's potential for boosting the efficiency and automation of color-based commodities sorting in production contexts. [10]
Development Of Industrial Automatic Multi Colour Sorting and Counting Machine Using Arduino Nano Microcontroller and TCS3200 Colour Sensor	Sachdeva, Amitesha	This article describes the creation of an industrial automatic multi-color sorting and counting system that makes use of an Arduino Nano microprocessor and a TCS3200 colour sensor. The author outlines the machine's design and execution, which includes a colour sensor to detect and differentiate between different colours. The system can categorise things based on their hues and count them accurately. The paper highlights the use of the Arduino Nano as the control system, which allows for efficient processing and decision-making. The experimental findings demonstrate the machine's ability to sort and count things in an industrial setting. This study advances the subject of

		industrial automation by giving a viable solution for automated colour sorting and counting operations that makes use of commonly available microcontrollers and colour sensors. [12]
Review on Recent Composite Gripper Concepts for Automotive Manufacturing	Minsch, N. Nosrat-Nezami, F. Gereke, T. Cherif, C.	This review focuses on the most recent improvements in composite gripper designs built primarily for automobile production processes. The authors present a thorough description of the various composite materials utilised in gripper construction and describe their benefits over typical metallic grippers, such as lower weight, higher energy efficiency, and increased flexibility. The paper focuses on current advances in composite gripper design, such as modular gripper systems, adaptive grippers, and grippers with embedded sensors for real-time monitoring. Furthermore, the authors discuss the difficulties involved with the application of composite grippers, such as structural integrity and endurance. This review serves as a significant resource for automotive engineers and researchers by synthesising current research and creative ideas, facilitating the application of composite grippers in the manufacturing industry. [15]

Soft Robotic Grippers	Shintake, Jun Cacucciolo, Vito Floreano, Dario Shea, Herbert	The authors investigate the design and development of grippers that use soft materials and compliant constructions, which provide advantages over typical rigid grippers. They go over the various actuation methods utilised in soft grippers, such as pneumatic, hydraulic, and shape memory alloys, as well as their advantages and disadvantages. The article discusses the various applications of soft robotic grippers in industries such as industrial automation, healthcare, and prosthetics. The authors emphasise the possibility of enhanced adaptability, agility, and safe contact with sensitive things. The study emphasises the importance of soft robotic grippers in increasing the capabilities and diversity of robotic systems across multiple domains. [16]
Soft manipulators and grippers: A review	Hughes, Josie Culha, Utku Giardina, Fabio Guenther, Fabian Rosendo, Andre Iida, Fumiya	This in-depth examination examines breakthroughs in soft manipulators and grippers, shining light on their prospective applications and emphasising recent developments in the field. The authors discuss the characteristics and benefits of soft robotics, emphasising their capacity to adapt to complicated contexts and securely interact with humans. The study discusses a variety of soft manipulation approaches, such as bio-inspired

		designs, pneumatic systems, and smart materials. The paper also discusses control and sensing issues, as well as the incorporation of soft manipulators into real-world applications. This study is a significant resource for researchers and engineers working in the subject of soft robotics by analysing the current state of the art and exploring future directions. [17]
Overview of microgrippers and design of a micro-manipulation station based on a MMOC microgripper	Agnus, Joël Nectoux, Patrick Chaillet, Nicolas	This study presents an in-depth description of microgrippers, concentrating on their design concepts and uses, as well as the building of a micro-manipulation station employing an MMOC (Monolithic Micro-Optical Circuit) microgripper. The authors look at the essential features and challenges of microgripper design, such as miniaturisation, actuation systems, and material selection. They address the advantages and limits of various types of microgrippers, such as electrothermal, electrostatic, and shape memory alloy-based grippers. The study also includes a thorough description of the micro-manipulation station, which incorporates the MMOC microgripper for accurate and controlled micro-object manipulation. This work is a great resource for

		academics and engineers working on micro-manipulation systems, demonstrating the potential of MMOC microgrippers in this sector. [18]
Automated colored object sorting application for robotic arms	R. Szabo and I. Lie	This artile describes an automated coloured object sorting application for robotic arms. The authors discuss the system's creation, which use computer vision algorithms to recognise and identify coloured items. The application interfaces with robotic arms to assist color-based sorting. The study addresses the object recognition method as well as the design of a feedback control system for precise and efficient sorting. The experimental findings show that the programme is capable of accurately sorting coloured objects. This study contributes to the field of automation by demonstrating the potential of computer vision and robotic arm integration in industrial applications by giving a viable solution for automated sorting jobs. [26]
A color-sorting SCARA robotic arm	Nkomo, Malvin Collier, Michael	The design and development of a color-sorting SCARA (Selective Compliance Assembly Robot Arm) robotic arm is presented in this article. The authors discuss the design of the robotic arm, which includes an RGB (Red, Green, Blue) colour sensor for colour identification and a

		gripper for color-sorting objects. The study describes the control system architecture, which incorporates colour recognition and manipulation planning image processing algorithms. The authors also detail the experimental results, demonstrating the robotic arm's ability to appropriately categorise things depending on their colours. This study advances the subject of automation by demonstrating a practical implementation of a SCARA robotic arm for color-based sorting tasks, with possible applications in industries such as manufacturing and logistics. [31]
Development of a vision based object classification system for an industrial robotic manipulator	Köker, Raşit Öz, Cemil Ferikoğlu, Abdullah	This publication focuses on the design of a vision-based object categorization system for an industrial robotic manipulator. The authors present the system's architecture and implementation, which uses computer vision algorithms to classify objects based on their visual characteristics. The algorithms used for object identification, feature extraction, and classification are discussed in the study. Based on the categorization results, the system connects with an industrial robotic manipulator to enable autonomous object handling. The experimental

		findings show that the system is accurate and efficient at classifying different objects in real-time. This study contributes to the field of industrial automation by demonstrating the potential of vision-based object classification for boosting the capabilities and efficiency of robotic manipulators in industrial settings. [37]
Development of Prismatic robotic arms for rehabilitation by using Electromygram (EMG)	Ali, Abdul Malik M. Kadir, Kushsairy Billah, Md Masum Yosuf, Zulkhairi Janin, Zuriati	The development of prismatic robotic arms for rehabilitation purposes is described in this journal, with a focus on the integration of electromyogram (EMG) information. The authors describe the design and construction of the robotic arms, which are specifically designed to aid in patient rehabilitation. EMG signals are used to control the movement and functionality of the robotic arms, allowing patients to complete exercises and restore motor abilities. The study goes through how signal processing methods are used to interpret EMG signals and generate appropriate control commands. The testing results show that prismatic robotic arms can help with rehabilitation efforts. This study advances the field of medical robotics by demonstrating the potential of EMG-based control systems in

		facilitating patient rehabilitation and enhancing motor abilities. [38]
Introduction to Microcontrollers	Bannatyne, Ross Viot, Greg	The authors give a brief overview of the core principles and components of microcontrollers, such as their architecture, programming languages, and interface capabilities. The journal delves at the various businesses and fields in which microcontrollers play an important role, such as embedded systems, robotics, and Internet of Things (IoT) devices. Bannatyne and Viot talk about the benefits and drawbacks of microcontroller programming, as well as the numerous programming paradigms and development tools accessible. The journal is an excellent resource for those who want to learn the fundamentals of microcontrollers and how they may be used to fuel innovative technological solutions in a variety of fields. [42]
Arduino Micro	Arduino.cc	A detailed reference to the Arduino Micro board, a versatile microcontroller platform. The magazine presents an overview of the Arduino Micro's core characteristics and capabilities, emphasising its small size and extensive set of functionalities. The writers go into the technical details of the board, such as its

		microcontroller chip, memory capacity, and input/output choices. The journal also discusses programming, providing information on the Arduino programming language and development environment. Arduino.cc teaches how to use the Arduino Micro for a variety of applications, including robotics, automation, and sensor interfacing, using practical examples and code snippets. This magazine is a wonderful resource for both new and seasoned makers, providing a thorough overview of the Arduino Micro and its enormous potential for creative and imaginative projects. [52]
Introduction to IoT Systems	Khan, Jamil Y.	provides a thorough review of Internet of Things (IoT) technology and their significance in today's environment. The author explains IoT in detail, demonstrating how it connects numerous devices, sensors, and networks to enable smooth data interchange and automation. Khan delves into the major components of IoT systems, such as hardware, software, and cloud infrastructure, emphasising their roles in data collection, processing, and analysis. The journal delves at the many applications of IoT systems, including smart cities, healthcare, agriculture, and industry. Khan

		also discusses the issues connected with IoT implementation, such as security, privacy, and scalability. This publication provides an excellent introduction to IoT systems, providing readers with a thorough understanding of their architecture, benefits, and possible societal influence. [61]

2.9 Summary

This review focuses on the creation of an IoT-based automatic object sorter employing a robot arm and a microcontroller. Because of its capacity to increase efficiency and accuracy, automated item sorting systems have grown in popularity. Robot arms are critical components in these systems, offering precision and dexterity for item manipulation. For manipulation activities, grippers such as vacuum grippers, pneumatic grippers, hydraulic grippers, and servo-electric grippers are essential. Colour sensors, in particular the TCS3200 sensor, allow for colour detection and sorting. Servo motors ensure precise movement, and the system is controlled by the Arduino UNO microcontroller. Integration of IoT enables real-time data collection, analysis, and control. The project's goal is to create an efficient and accurate sorting system that reduces sorting expenses and time.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will clarify the descriptions for "IoT Based Automatic Object Color Sorter Using A Robot Arm and Microcontroller" that will be done in detail thoroughly. This project consists of two parts which are hardware and software.

3.2 Flowchart

Project flowcharts are used to depict and explain the flow of a system in a simple figure. Flowcharts fulfil their goal in the most basic form by identifying the project's working criteria. The method and steps of the project were to be laid out as a diagram that displays the system from the beginning to the finish using flowcharts.

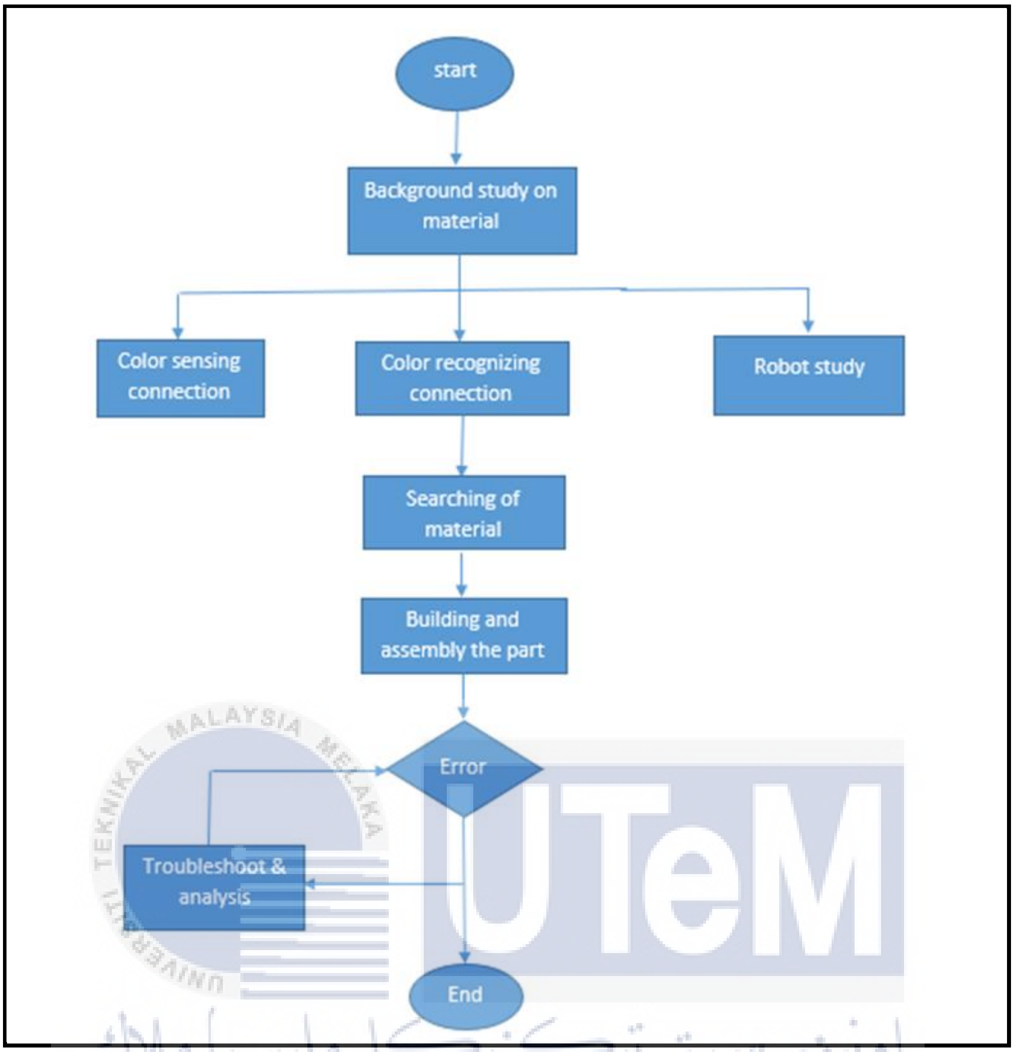

FIGURE 3-1 Hardware Flowchart

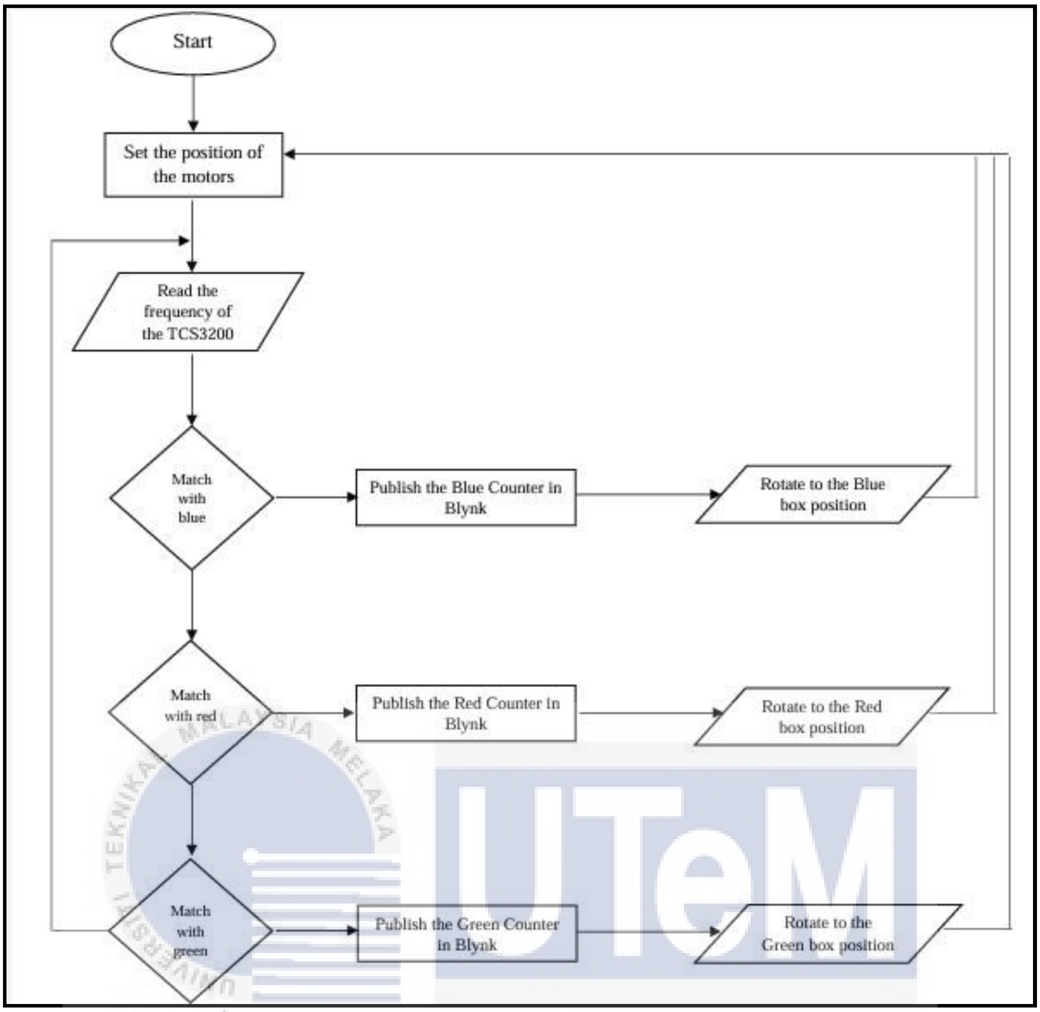

FIGURE 3-2 Software Flowchart

3.3 Block Diagram

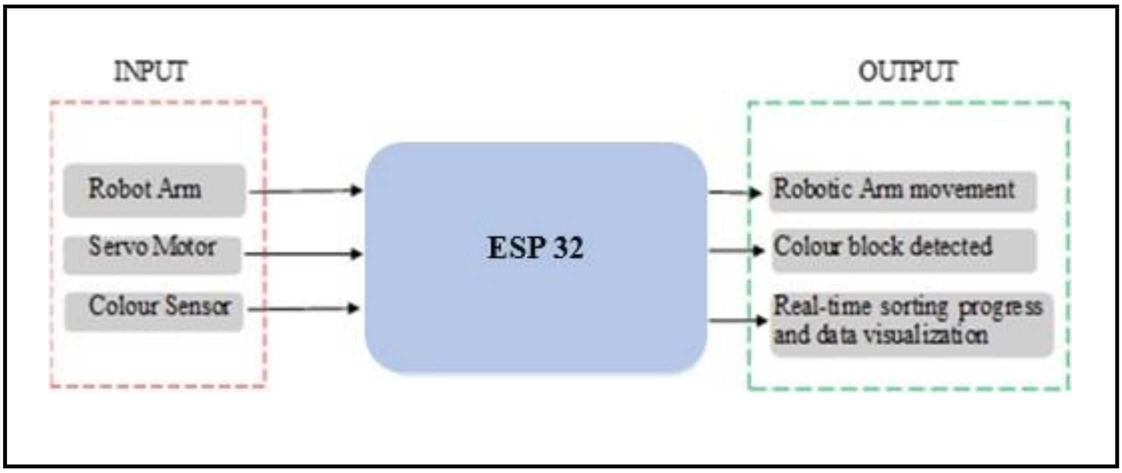

FIGURE 3-3 Project Block Diagram

3.4 Hardware Development

This section of the report describes the appropriate project components and materials. This project combines hardware and software. This project's hardware inputs and outputs include the robot arm, robot arm gripper, servo motor, colour sensor, ESP32 and colour block. The following are descriptions of each and every substance utilised.

3.4.1 Hardware Design

This section of the report describes the appropriate project components and materials. This project combines hardware and software. This project's hardware inputs and outputs include the robot arm, robot arm gripper, servo motor, colour sensor, ESP32 and colour block. The following are descriptions of each and every substance utilised..

3.4.2 Components

3.4.2.1 Robot Arms

A four-degree-of-freedom (DOF) robot arm is a robotic arm system with four independently moving joints or axes of motion. Base rotation, shoulder rotation, elbow rotation, and wrist rotation are examples of these. These joints allow the arm to move horizontally, vertically, and bend, allowing for accurate positioning and handling of three-dimensional items. The four-degree-of-freedom robot arm is widely utilised in manufacturing, automation, research, and teaching. It provides a good blend of usefulness and intricacy, allowing you to do things like choose and place objects and assemble components.

FIGURE 3-4 4DOF Robot Arm [69]

3.4.2.2 Robotic Arm Gripper

A claw gripper is a device that can be attached to a robot arm to improve its manipulation capabilities. It is made up of opposing jaws or fingers that may open and close to securely grab items, making it useful for a wide range of applications. The gripper's design allows it to adapt to different objects by altering the spacing and angle of its jaws, allowing for precise and solid gripping. For greater grip and sensitive handling, some claw grippers have specialised characteristics such as rubberized or articulated fingertips. The gripper, which is integrated with the control system of the robot arm, can be controlled by actuators and sensors, allowing synchronised motions for activities such as pick-and-place operations, assembly, sorting, and packaging.

The gripper is attached to the robot arm through a secure mounting mechanism, allowing for simple attachment and replacement based on task needs. The installation of a claw gripper allows the robot arm to interact with its surroundings by gripping and manipulating objects effectively. As a result, it is a valuable tool in industries such as manufacturing, shipping, warehouse automation, and research, where accurate object manipulation is essential.

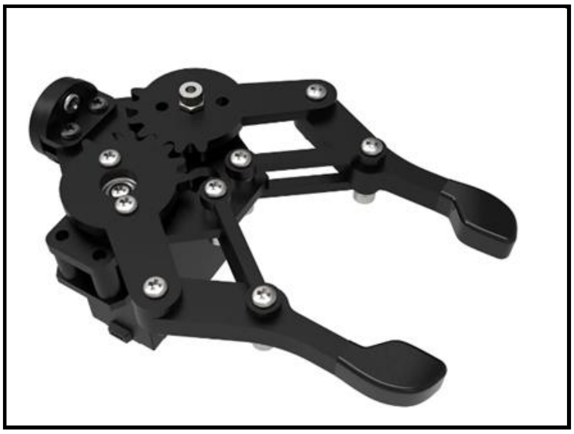

FIGURE 3-5 Claw Gripper [25]

3.4.2.3 ESP 32

The ESP32 is a powerful System on Chip (SoC) microcontroller developed by Espressif Systems. It serves as an advanced successor to the ESP8266, offering integrated Wi-Fi 802.11 b/g/n, dual-mode Bluetooth version 4.2, and various peripherals. Notable improvements include two cores clocked up to 240 MHz, an increased number of GPIO pins from 17 to 36, and 16 PWM channels. With 4MB of flash memory, the ESP32 caters to diverse applications such as smart home systems, automation, wearables, audio applications, and cloud-based IoT. The SoC incorporates a Tensilica Xtensa LX6 processor, with some variations featuring a dual-core Xtensa LX7 or a single-core RISC-V microprocessor. Additional features encompass cryptographic hardware acceleration (AES, SHA-2, RSA, ECC), a random number generator, and various communication interfaces like SPI, I2S, I2C, CAN, UART, Ethernet MAC, and IR. The ESP32 is available in different versions, including the ESP32 Developer Kit, ESP32 Wrover Kit with an SD card and 3.2" LCD display, and the ESP32 Azure IoT kit with USB Bridge and built-in sensors, catering to a range of development needs from different manufacturers such as SparkFun, WeMoS, Adafruit, DF Robot, and others. The series showcases versatility in prototype designs suitable for diverse applications in the IoT landscape [60][70].

3.4.2.4 MG90S Servo Motor

The MG90S servo motor is a small and light motor that is often utilised in robotic applications such as 4DOF robot arms. It provides fine control over angular motion and is well-known for its dependability and low cost. The MG90S is powered by a feedback control system that includes a DC motor, gear mechanism, and position feedback potentiometer. This enables the motor to hold and control its position precisely, allowing for exact angular movement. One of its distinguishing features is its high torque-to-size ratio, which makes it suited for applications requiring strength and precision. The MG90S servo motor is also well-known for its ease of integration, with a three-wire interface commonly used for power, ground, and control signal.

Because of its simplicity, it is compatible with a wide range of microcontrollers and control systems. Furthermore, the MG90S frequently uses metal gears, which provide durability and improved performance under stress. In conclusion, the MG90S servo motor is a dependable and cost-effective option for robotic applications, providing accurate control, a high torque-to-size ratio, and ease of integration. Its qualities make it ideal for 4DOF robot arms, giving the strength and precision required for angular motion control.

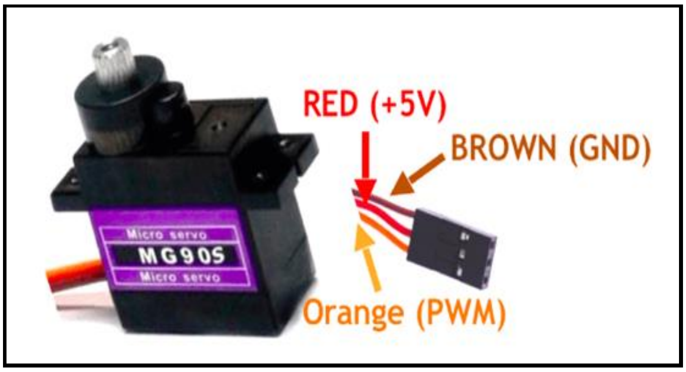

FIGURE 3-6 MG90S Servo Motor [71]

3.4.2.5 TCS3200 Colour Sensor

The TCS3200 colour sensor is a versatile component that is often used to enable colour sensing capabilities in robot arms. It is made up of photodiodes and RGB filters, which allow it to detect and differentiate between colours properly. When the sensor is integrated into a robot arm, it gains the capacity to recognise and sort objects based on their colours, making it useful for automation processes and color-based decision-making activities.

The TCS3200 colour sensor is usually installed on the end effector of the robot arm or another suitable location within reach. It collects colour information by illuminating objects and measuring the reflected light using photodiodes. The RGB filters allow the sensor to monitor the intensity of red, green, and blue light, resulting in useful colour data.

Interfacing the TCS3200 sensor with a microcontroller or control system capable of processing colour data is required for integration. This enables the robot arm to evaluate sensor signals and make decisions or initiate actions depending on the received colour information.

To summarise, the TCS3200 colour sensor improves the capabilities of a robot arm by giving colour sensing functionality. Color-based object sorting, identification, and automation procedures that rely on color-based decision-making are all possible with it. The robot arm acquires the capacity to interact intelligently with its environment based on colour information by including the TCS3200 colour sensor, opening up a wide range of applications in robotics, automation, and colour detection systems.

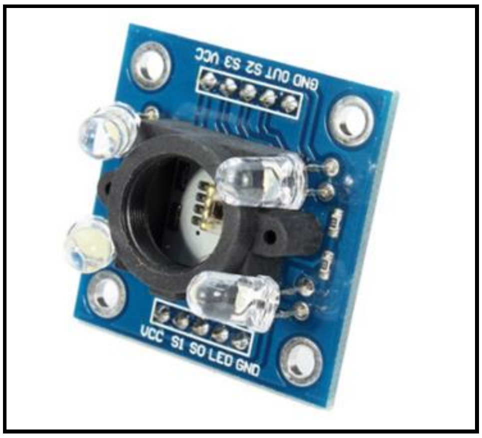

FIGURE 3-7 TCS3200 Color Sensor [72]

3.5 Software Development

3.5.1 Arduino IDE

The Arduino Integrated Development Environment (IDE) is a cross-platform application written in the Java programming language that is given by Arduino. It was created for people who may not be familiar with computers. It provides a code editor with features such as syntax highlighting, appropriate braces, cutting or copying text, scanning or deleting text, and automated indentation, as well as a one-click compilation and uploading method for Arduino boards. A message area, a text terminal, a toolbar with usual feature buttons, and a series of menus are also featured.

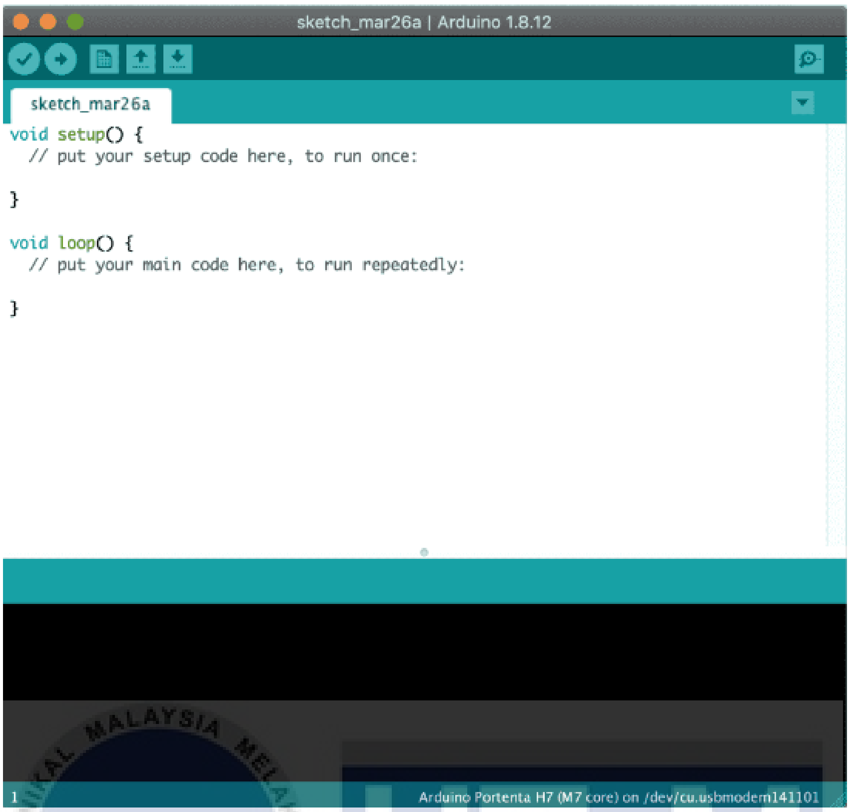

FIGURE 3-8 Arduino IDE

3.5.2 Serial Monitor

The Serial Monitor stands as an indispensable tool within the Arduino Integrated Development Environment (IDE), assuming a pivotal role in the development and debugging of Arduino projects. With its integration directly into the IDE editor in Arduino IDE 2, the Serial Monitor eliminates the need for external windows, offering a streamlined and cohesive user experience. Users can effortlessly access this tool by employing the magnifying glass icon in the upper right corner, navigating through the "Tools" menu, or utilizing keyboard shortcuts (e.g., **Ctrl + Shift + M** on Windows/Linux or **Cmd + Shift + M** on Mac).

A distinctive feature of the Arduino IDE 2 is its support for multiple editor windows, each capable of hosting its dedicated instance of the Serial Monitor. This functionality proves particularly advantageous when managing diverse aspects of code development or concurrently monitoring the serial output of several Arduino boards. Furthermore, the Serial Monitor facilitates seamless communication between the computer and the Arduino board by allowing users to select the appropriate baud rate. The ability to input data directly into the Serial Monitor's interface enhances its utility, enabling users to test and interact with their Arduino projects with precision.

In summary, the integrated Serial Monitor in Arduino IDE 2 underscores its significance as a sophisticated debugging and communication tool. Its seamless integration into the IDE, support for multiple windows, and flexibility in baud rate selection contribute to an efficient and comprehensive development environment for Arduino enthusiasts.

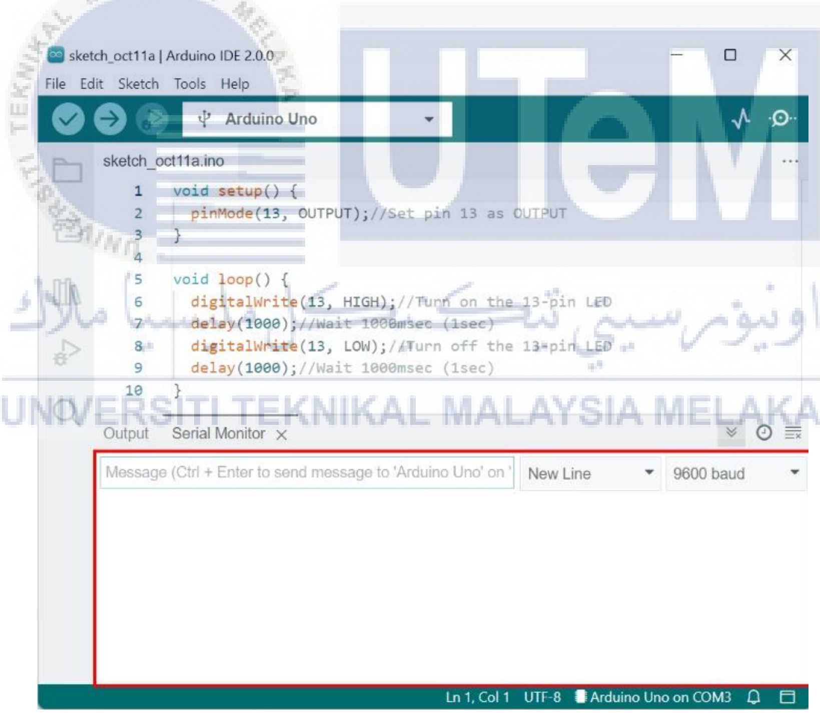

FIGURE 3-9 Serial Monitor

3.5.3 Blynk Application

Blynk is an application software meant to make it easier to create mobile interfaces for IoT applications. It provides a user-friendly platform where users may connect hardware devices to a mobile app and customise the interface to their specific needs. Users may simply construct and organise widgets such as buttons, sliders, and graphs using a drag-and-drop interface to create visually appealing control panels.

To establish a secure connection between the mobile app and the hardware devices, Blynk offers numerous communication channels such as Wi-Fi, Bluetooth, and cellular data. It allows users to operate the devices and receive real-time data from them by sending orders from the app. Data logging, push alerts, and connectivity with cloud services and APIs are also included in the software.

Blynk's broad interoperability with many hardware and software platforms is one of its distinguishing features. It supports a wide range of microcontrollers, development boards, and IoT modules, making it suitable for users of varying skill levels.

In essence, Blynk makes it easier to create mobile interfaces for IoT projects by offering a user-friendly platform with drag-and-drop capability. It supports a wide range of hardware, has secure communication channels, and includes features such as data logging and push alerts. Users can quickly construct customised mobile apps to control and monitor their IoT devices with Blynk, making it a great tool for both IoT hobbyists and experts.

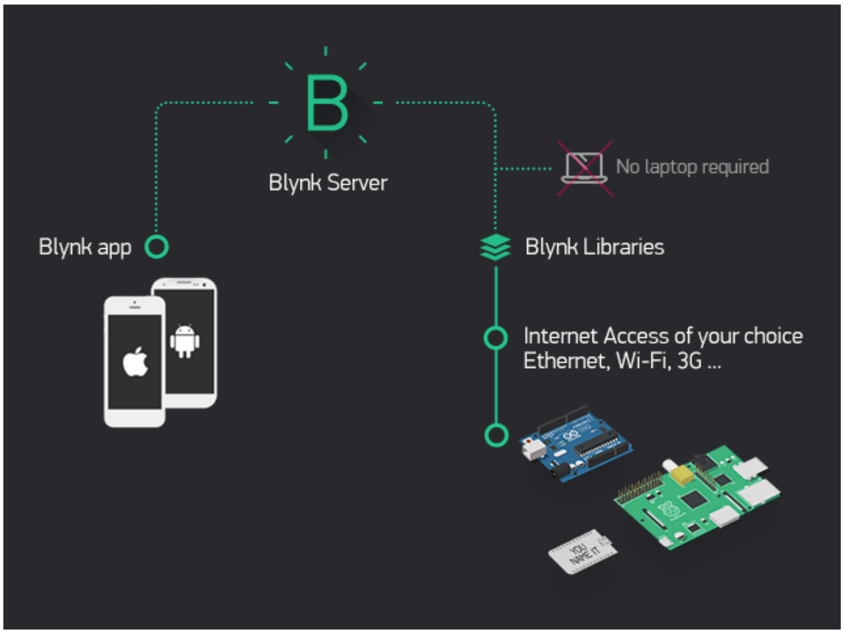

FIGURE 3-10 Blynk Software Concept

3.6 Summary

The methods used in constructing an IoT-based automatic object sorter employing a robot arm and a microcontroller is the subject of this chapter. The four-degree-of-freedom robot arm, robotic arm gripper, Arduino Uno microcontroller, ESP8266 Wi-Fi module, MG90S servo motor, TCS3200 colour sensor, Blynk application for mobile interfaces, and Proteus simulation software are among the major components described. The chapter emphasises each component's capabilities and applications, emphasising their roles in producing accurate and efficient object sorting. The project's goal is to integrate these components to build a real-time monitoring and control system that reduces sorting costs and time.

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 Introduction

This chapter present the result and finding of the data for the color sensor and Blynk application. This part contains the results, analysis, and discussion of all data obtained from the system in order to determine its performance.

4.2 Results and Analysis

4.2.1 System Functionality

The IoT-based automatic object color sorter system employs a TCS3200 color sensor to detect red, blue, and green colors, with an ESP32 microcontroller processing the data and directing a 4DOF robot arm with MG90S servo motors. Integrated with the Blynk app, users can manually control the robot arm via a slider interface for adjustments and testing. When a color is detected, the robot arm moves to a predefined angle for automated sorting, enhancing efficiency. Real-time monitoring and alerts through the Blynk app provide users with immediate feedback on the sorting process, ensuring a versatile and user-friendly solution for color-based object sorting.

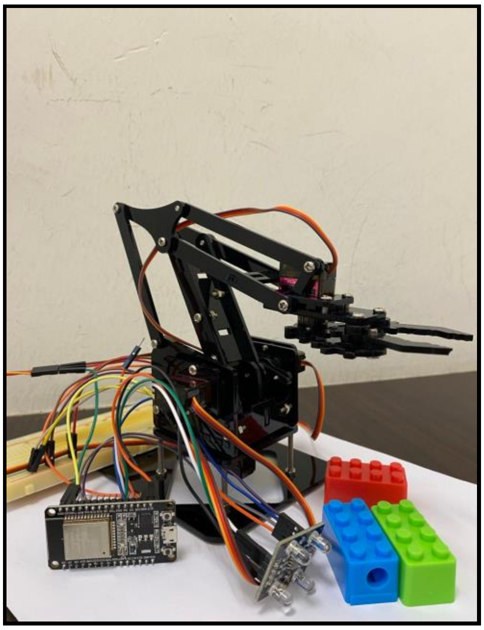

FIGURE 4-1 Overall Hardware Prototype

4.2.2 Hardware Prototype View

This section shows that the actual view for the hardware prototype display from the top, left, front and back side views. The main component required in Figure ?? is the ESP 32 microcontroller, which is connected to a robot arm and color sensor.

The wiring connections for the hardware prototype involve integrating the ESP32 microcontroller with the robot arm and TCS3200 color sensor. The ESP32 connects to the servo motors on the robot arm through GPIO pins for precise control. Ensure proper wiring for the power and ground connections between the ESP32 and the servo motors. Additionally, establish a communication link between the ESP32 and the TCS3200 color sensor, connecting the necessary pins for data transmission. This arrangement facilitates coordinated control, allowing the microcontroller to manage the robot arm's movement based on color sensor input.

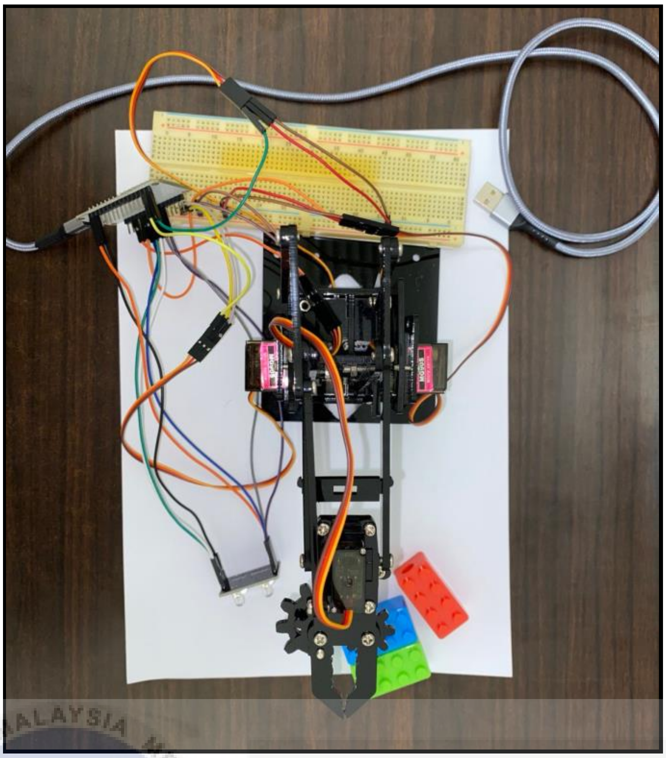

FIGURE 4-2 Top View

FIGURE 4-3 Left Side View

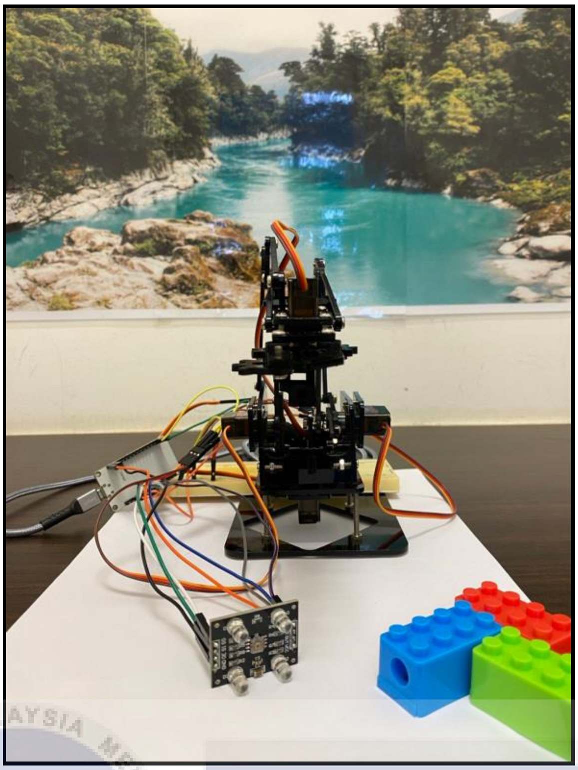

FIGURE 4-4 Front View

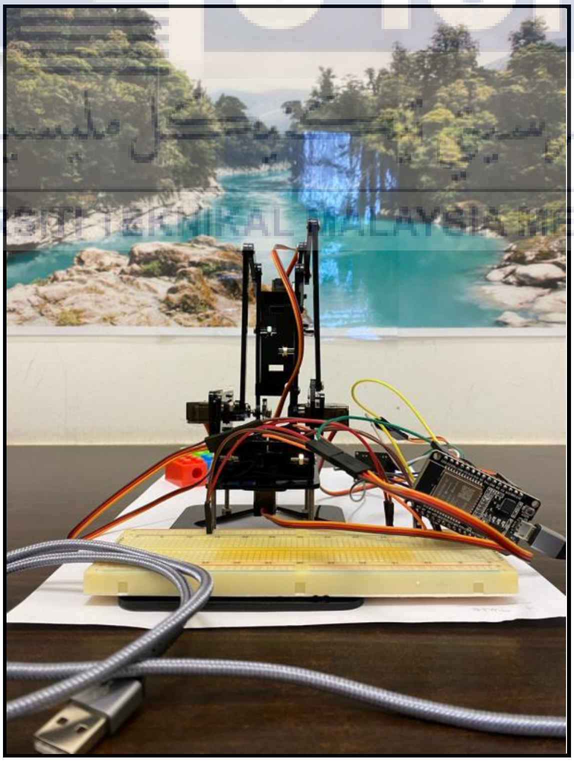

FIGURE 4-5 Back View

4.3 TCS 3200 Color Sensor Analysis

On this part, data from the color sensor was extracted and examined using the Serial Monitor in the Arduino IDE. The data was divided into two primary considerations: the ambient light conditions and the specified color ranges for the targeted color block. Ensuring optimal lighting and accurately selecting color ranges for the block were crucial steps. This precision was vital to maintain a consistent value, allowing for a narrow tolerance range of just 10 units. This meticulous approach was essential for ensuring the reliability and overall effectiveness of the system.

Table 4-1 Output for Color Sensor in Bright Color Block and White Light

Ambient Light / Bright Color	White Light
Red	Red PW = 22 - Green PW = 63 - Blue PW = 48 Red PW = 22 - Green PW = 68 - Blue PW = 54 Red PW = 20 - Green PW = 70 - Blue PW = 51 Red PW = 20 - Green PW = 71 - Blue PW = 52 Red PW = 20 - Green PW = 72 - Blue PW = 52 Red PW = 20 - Green PW = 72 - Blue PW = 52 Red PW = 20 - Green PW = 72 - Blue PW = 51 Red PW = 20 - Green PW = 71 - Blue PW = 51 Red PW = 20 - Green PW = 71 - Blue PW = 51 Red PW = 20 - Green PW = 70 - Blue PW = 51 Red PW = 20 - Green PW = 70 - Blue PW = 50 Red PW = 20 - Green PW = 69 - Blue PW = 50 Red PW = 20 - Green PW = 69 - Blue PW = 50 Red PW = 19 - Green PW = 69 - Blue PW = 50 Red PW = 20 - Green PW = 69 - Blue PW = 50 Red PW = 19 - Green PW = 68 - Blue PW = 50 Red PW = 19 - Green PW = 68 - Blue PW = 49 Red PW = 19 - Green PW = 68 - Blue PW = 50 Red PW = 19 - Green PW = 68 - Blue PW = 50 Red PW = 19 - Green PW = 68 - Blue PW = 50 Red PW = 19 - Green PW = 68 - Blue PW = 50 Red PW = 19 - Green PW = 68 - Blue PW = 50 Red PW = 20 - Green PW = 68 - Blue PW = 50 Red PW = 19 - Green PW = 69 - Blue PW = 50 Red PW = 20 - Green PW = 69 - Blue PW = 51 Red PW = 20 - Green PW = 70 - Blue PW = 51 Red PW = 20 - Green PW = 71 - Blue PW = 52 Red PW = 20 - Green PW = 72 - Blue PW = 52 Red PW = 20 - Green PW = 72 - Blue PW = 52 Red PW = 20 - Green PW = 72 - Blue PW = 52 Red PW = 20 - Green PW = 72 - Blue PW = 51 Red PW = 20 - Green PW = 71 - Blue PW = 51

Green	Red PW = 37 - Green PW = 28 - Blue PW = 47 Red PW = 40 - Green PW = 30 - Blue PW = 44 Red PW = 37 - Green PW = 28 - Blue PW = 44 Red PW = 38 - Green PW = 28 - Blue PW = 43 Red PW = 37 - Green PW = 28 - Blue PW = 43 Red PW = 37 - Green PW = 28 - Blue PW = 43 Red PW = 36 - Green PW = 28 - Blue PW = 43 Red PW = 36 - Green PW = 28 - Blue PW = 42 Red PW = 36 - Green PW = 27 - Blue PW = 42 Red PW = 36 - Green PW = 28 - Blue PW = 42 Red PW = 35 - Green PW = 27 - Blue PW = 42 Red PW = 35 - Green PW = 27 - Blue PW = 42 Red PW = 35 - Green PW = 27 - Blue PW = 42 Red PW = 35 - Green PW = 27 - Blue PW = 42 Red PW = 35 - Green PW = 27 - Blue PW = 42 Red PW = 35 - Green PW = 27 - Blue PW = 42 Red PW = 35 - Green PW = 27 - Blue PW = 42 Red PW = 35 - Green PW = 27 - Blue PW = 42 Red PW = 36 - Green PW = 27 - Blue PW = 43 Red PW = 36 - Green PW = 28 - Blue PW = 43 Red PW = 37 - Green PW = 28 - Blue PW = 44 Red PW = 37 - Green PW = 28 - Blue PW = 44 Red PW = 37 - Green PW = 28 - Blue PW = 43 Red PW = 37 - Green PW = 28 - Blue PW = 43 Red PW = 37 - Green PW = 28 - Blue PW = 43 Red PW = 37 - Green PW = 28 - Blue PW = 43 Red PW = 36 - Green PW = 28 - Blue PW = 42 Red PW = 36 - Green PW = 28 - Blue PW = 42 Red PW = 36 - Green PW = 28 - Blue PW = 43 Red PW = 36 - Green PW = 28 - Blue PW = 43 Red PW = 36 - Green PW = 28 - Blue PW = 43
Blue	Red PW = 66 - Green PW = 38 - Blue PW = 19 Red PW = 64 - Green PW = 38 - Blue PW = 19 Red PW = 64 - Green PW = 38 - Blue PW = 19 Red PW = 63 - Green PW = 38 - Blue PW = 19 Red PW = 62 - Green PW = 38 - Blue PW = 19 Red PW = 62 - Green PW = 38 - Blue PW = 19 Red PW = 61 - Green PW = 38 - Blue PW = 19 Red PW = 60 - Green PW = 37 - Blue PW = 19 Red PW = 62 - Green PW = 38 - Blue PW = 19 Red PW = 63 - Green PW = 38 - Blue PW = 19 Red PW = 62 - Green PW = 38 - Blue PW = 19 Red PW = 62 - Green PW = 38 - Blue PW = 19 Red PW = 62 - Green PW = 38 - Blue PW = 19 Red PW = 62 - Green PW = 38 - Blue PW = 20 Red PW = 62 - Green PW = 38 - Blue PW = 19 Red PW = 63 - Green PW = 38 - Blue PW = 19 Red PW = 63 - Green PW = 38 - Blue PW = 19 Red PW = 64 - Green PW = 38 - Blue PW = 20 Red PW = 65 - Green PW = 38 - Blue PW = 20 Red PW = 66 - Green PW = 39 - Blue PW = 20 Red PW = 67 - Green PW = 39 - Blue PW = 20 Red PW = 67 - Green PW = 39 - Blue PW = 20 Red PW = 67 - Green PW = 39 - Blue PW = 20 Red PW = 67 - Green PW = 39 - Blue PW = 20 Red PW = 66 - Green PW = 38 - Blue PW = 20 Red PW = 65 - Green PW = 38 - Blue PW = 20 Red PW = 64 - Green PW = 38 - Blue PW = 19 Red PW = 63 - Green PW = 38 - Blue PW = 19 Red PW = 63 - Green PW = 38 - Blue PW = 19 Red PW = 62 - Green PW = 38 - Blue PW = 19 Red PW = 62 - Green PW = 38 - Blue PW = 19 Red PW = 62 - Green PW = 38 - Blue PW = 19

According to the information presented in Table 4-1, the output data indicates a tolerance value of less than 20. This particular value is considered optimal, signifying an excellent performance of the color sensor in accurately detecting and representing the true colors.

Table 4-2 Output for Color Sensor in Dark Color Block and White Light

Ambient Light / Dark Color	White Light
Red	Red PW = 25 - Green PW = 66 - Blue PW = 49 Red PW = 25 - Green PW = 66 - Blue PW = 49 Red PW = 25 - Green PW = 65 - Blue PW = 48 Red PW = 24 - Green PW = 65 - Blue PW = 48 Red PW = 24 - Green PW = 64 - Blue PW = 48 Red PW = 24 - Green PW = 64 - Blue PW = 47 Red PW = 24 - Green PW = 63 - Blue PW = 47 Red PW = 24 - Green PW = 63 - Blue PW = 47 Red PW = 23 - Green PW = 63 - Blue PW = 47 Red PW = 23 - Green PW = 63 - Blue PW = 47 Red PW = 24 - Green PW = 63 - Blue PW = 47 Red PW = 23 - Green PW = 63 - Blue PW = 47 Red PW = 23 - Green PW = 63 - Blue PW = 47 Red PW = 24 - Green PW = 63 - Blue PW = 47 Red PW = 24 - Green PW = 63 - Blue PW = 47 Red PW = 24 - Green PW = 63 - Blue PW = 48 Red PW = 24 - Green PW = 64 - Blue PW = 48 Red PW = 24 - Green PW = 65 - Blue PW = 48 Red PW = 24 - Green PW = 65 - Blue PW = 49 Red PW = 24 - Green PW = 66 - Blue PW = 49 Red PW = 25 - Green PW = 66 - Blue PW = 50 Red PW = 25 - Green PW = 67 - Blue PW = 50 Red PW = 26 - Green PW = 67 - Blue PW = 50 Red PW = 26 - Green PW = 67 - Blue PW = 50 Red PW = 26 - Green PW = 67 - Blue PW = 50 Red PW = 26 - Green PW = 67 - Blue PW = 49 Red PW = 25 - Green PW = 67 - Blue PW = 50 Red PW = 26 - Green PW = 69 - Blue PW = 50 Red PW = 26 - Green PW = 69 - Blue PW = 50 Red PW = 26 - Green PW = 68 - Blue PW = 50 Red PW = 25 - Green PW = 68 - Blue PW = 49 Red PW = 25 - Green PW = 67 - Blue PW = 49
Green	Red PW = 75 - Green PW = 52 - Blue PW = 51 Red PW = 75 - Green PW = 52 - Blue PW = 52 Red PW = 76 - Green PW = 52 - Blue PW = 52 Red PW = 76 - Green PW = 52 - Blue PW = 52 Red PW = 77 - Green PW = 52 - Blue PW = 52 Red PW = 78 - Green PW = 52 - Blue PW = 53 Red PW = 80 - Green PW = 53 - Blue PW = 53 Red PW = 81 - Green PW = 53 - Blue PW = 53 Red PW = 82 - Green PW = 54 - Blue PW = 53 Red PW = 83 - Green PW = 54 - Blue PW = 53 Red PW = 82 - Green PW = 53 - Blue PW = 53 Red PW = 81 - Green PW = 53 - Blue PW = 53 Red PW = 83 - Green PW = 54 - Blue PW = 53 Red PW = 83 - Green PW = 54 - Blue PW = 53 Red PW = 83 - Green PW = 54 - Blue PW = 53 Red PW = 82 - Green PW = 54 - Blue PW = 53 Red PW = 82 - Green PW = 54 - Blue PW = 53 Red PW = 81 - Green PW = 53 - Blue PW = 53 Red PW = 81 - Green PW = 53 - Blue PW = 53 Red PW = 80 - Green PW = 53 - Blue PW = 53 Red PW = 80 - Green PW = 53 - Blue PW = 53 Red PW = 80 - Green PW = 53 - Blue PW = 53 Red PW = 80 - Green PW = 53 - Blue PW = 53 Red PW = 80 - Green PW = 53 - Blue PW = 53 Red PW = 81 - Green PW = 53 - Blue PW = 53 Red PW = 81 - Green PW = 53 - Blue PW = 53 Red PW = 81 - Green PW = 54 - Blue PW = 53 Red PW = 82 - Green PW = 54 - Blue PW = 53 Red PW = 82 - Green PW = 54 - Blue PW = 54 Red PW = 83 - Green PW = 54 - Blue PW = 54 Red PW = 84 - Green PW = 54 - Blue PW = 54 Red PW = 84 - Green PW = 54 - Blue PW = 54

Blue	Red PW = 76 - Green PW = 58 - Blue PW = 28 Red PW = 76 - Green PW = 59 - Blue PW = 28 Red PW = 77 - Green PW = 59 - Blue PW = 28 Red PW = 79 - Green PW = 59 - Blue PW = 28 Red PW = 80 - Green PW = 59 - Blue PW = 28 Red PW = 81 - Green PW = 60 - Blue PW = 28 Red PW = 83 - Green PW = 60 - Blue PW = 28 Red PW = 83 - Green PW = 60 - Blue PW = 28 Red PW = 83 - Green PW = 60 - Blue PW = 28 Red PW = 83 - Green PW = 60 - Blue PW = 28 Red PW = 83 - Green PW = 60 - Blue PW = 28 Red PW = 82 - Green PW = 60 - Blue PW = 28 Red PW = 81 - Green PW = 60 - Blue PW = 28 Red PW = 80 - Green PW = 59 - Blue PW = 28 Red PW = 79 - Green PW = 59 - Blue PW = 27 Red PW = 78 - Green PW = 59 - Blue PW = 27 Red PW = 77 - Green PW = 58 - Blue PW = 27 Red PW = 76 - Green PW = 58 - Blue PW = 27 Red PW = 75 - Green PW = 58 - Blue PW = 27 Red PW = 76 - Green PW = 59 - Blue PW = 28 Red PW = 80 - Green PW = 60 - Blue PW = 28 Red PW = 80 - Green PW = 60 - Blue PW = 28 Red PW = 81 - Green PW = 60 - Blue PW = 28 Red PW = 81 - Green PW = 60 - Blue PW = 28 Red PW = 81 - Green PW = 60 - Blue PW = 28 Red PW = 81 - Green PW = 60 - Blue PW = 28 Red PW = 82 - Green PW = 61 - Blue PW = 28 Red PW = 83 - Green PW = 61 - Blue PW = 28 Red PW = 85 - Green PW = 61 - Blue PW = 28 Red PW = 85 - Green PW = 61 - Blue PW = 28 Red PW = 86 - Green PW = 61 - Blue PW = 28

In reference to the data presented in Table 4-2 above, the output data reveals a tolerance value of less than 20. However, it is noteworthy to highlight that the resultant value exhibits inconsistency, indicating variations in the accuracy or reliability of the color sensor's performance.

Table 4-3 Output for Color Sensor in Bright Color Block and Yellow Light

Ambient Light / Bright Color	Yellow Light
Red	Red PW = 23 - Green PW = 77 - Blue PW = 57 Red PW = 24 - Green PW = 77 - Blue PW = 57 Red PW = 24 - Green PW = 78 - Blue PW = 57 Red PW = 24 - Green PW = 77 - Blue PW = 57 Red PW = 23 - Green PW = 75 - Blue PW = 53 Red PW = 20 - Green PW = 51 - Blue PW = 38 Red PW = 16 - Green PW = 47 - Blue PW = 36 Red PW = 15 - Green PW = 47 - Blue PW = 36 Red PW = 15 - Green PW = 47 - Blue PW = 37 Red PW = 15 - Green PW = 47 - Blue PW = 37 Red PW = 15 - Green PW = 47 - Blue PW = 36 Red PW = 12 - Green PW = 30 - Blue PW = 24 Red PW = 9 - Green PW = 29 - Blue PW = 23 Red PW = 9 - Green PW = 29 - Blue PW = 24 Red PW = 10 - Green PW = 29 - Blue PW = 24 Red PW = 10 - Green PW = 29 - Blue PW = 24 Red PW = 10 - Green PW = 28 - Blue PW = 24 Red PW = 10 - Green PW = 29 - Blue PW = 24 Red PW = 10 - Green PW = 29 - Blue PW = 25 Red PW = 11 - Green PW = 31 - Blue PW = 27 Red PW = 12 - Green PW = 35 - Blue PW = 28 Red PW = 12 - Green PW = 31 - Blue PW = 22 Red PW = 8 - Green PW = 26 - Blue PW = 31 Red PW = 7 - Green PW = 18 - Blue PW = 15 Red PW = 6 - Green PW = 18 - Blue PW = 15 Red PW = 7 - Green PW = 18 - Blue PW = 15 Red PW = 7 - Green PW = 18 - Blue PW = 15 Red PW = 7 - Green PW = 18 - Blue PW = 15 Red PW = 6 - Green PW = 18 - Blue PW = 15 Red PW = 7 - Green PW = 18 - Blue PW = 17 Red PW = 7 - Green PW = 19 - Blue PW = 15 Red PW = 6 - Green PW = 18 - Blue PW = 14
Green	Red PW = 43 - Green PW = 32 - Blue PW = 50 Red PW = 42 - Green PW = 33 - Blue PW = 50 Red PW = 42 - Green PW = 32 - Blue PW = 50 Red PW = 42 - Green PW = 33 - Blue PW = 51 Red PW = 42 - Green PW = 33 - Blue PW = 51 Red PW = 42 - Green PW = 32 - Blue PW = 50 Red PW = 42 - Green PW = 33 - Blue PW = 50 Red PW = 42 - Green PW = 33 - Blue PW = 50 Red PW = 42 - Green PW = 33 - Blue PW = 50 Red PW = 42 - Green PW = 33 - Blue PW = 50 Red PW = 42 - Green PW = 32 - Blue PW = 50 Red PW = 42 - Green PW = 33 - Blue PW = 50 Red PW = 42 - Green PW = 32 - Blue PW = 50 Red PW = 42 - Green PW = 32 - Blue PW = 50 Red PW = 38 - Green PW = 31 - Blue PW = 47 Red PW = 36 - Green PW = 30 - Blue PW = 40 Red PW = 29 - Green PW = 28 - Blue PW = 39 Red PW = 26 - Green PW = 25 - Blue PW = 33 Red PW = 23 - Green PW = 25 - Blue PW = 34 Red PW = 22 - Green PW = 22 - Blue PW = 22 Red PW = 10 - Green PW = 13 - Blue PW = 14 Red PW = 8 - Green PW = 13 - Blue PW = 14 Red PW = 9 - Green PW = 13 - Blue PW = 15 Red PW = 9 - Green PW = 13 - Blue PW = 14 Red PW = 9 - Green PW = 13 - Blue PW = 14 Red PW = 9 - Green PW = 13 - Blue PW = 14 Red PW = 8 - Green PW = 12 - Blue PW = 13 Red PW = 8 - Green PW = 12 - Blue PW = 13 Red PW = 8 - Green PW = 12 - Blue PW = 13 Red PW = 8 - Green PW = 11 - Blue PW = 13 Red PW = 8 - Green PW = 11 - Blue PW = 13 Red PW = 7 - Green PW = 11 - Blue PW = 13

Blue	Red PW = 82 - Green PW = 48 - Blue PW = 24 Red PW = 82 - Green PW = 48 - Blue PW = 24 Red PW = 82 - Green PW = 48 - Blue PW = 24 Red PW = 82 - Green PW = 48 - Blue PW = 24 Red PW = 82 - Green PW = 48 - Blue PW = 24 Red PW = 81 - Green PW = 48 - Blue PW = 24 Red PW = 81 - Green PW = 48 - Blue PW = 24 Red PW = 81 - Green PW = 46 - Blue PW = 23 Red PW = 73 - Green PW = 47 - Blue PW = 23 Red PW = 51 - Green PW = 42 - Blue PW = 23 Red PW = 56 - Green PW = 43 - Blue PW = 22 Red PW = 55 - Green PW = 42 - Blue PW = 22 Red PW = 55 - Green PW = 42 - Blue PW = 22 Red PW = 53 - Green PW = 42 - Blue PW = 22 Red PW = 48 - Green PW = 40 - Blue PW = 22 Red PW = 70 - Green PW = 45 - Blue PW = 21 Red PW = 34 - Green PW = 50 - Blue PW = 32 Red PW = 92 - Green PW = 60 - Blue PW = 32 Red PW = 92 - Green PW = 61 - Blue PW = 32 Red PW = 92 - Green PW = 61 - Blue PW = 32 Red PW = 92 - Green PW = 60 - Blue PW = 32 Red PW = 86 - Green PW = 58 - Blue PW = 30 Red PW = 27 - Green PW = 25 - Blue PW = 15 Red PW = 11 - Green PW = 20 - Blue PW = 14 Red PW = 10 - Green PW = 14 - Blue PW = 10 Red PW = 7 - Green PW = 12 - Blue PW = 9 Red PW = 7 - Green PW = 12 - Blue PW = 9 Red PW = 8 - Green PW = 13 - Blue PW = 10 Red PW = 8 - Green PW = 13 - Blue PW = 10 Red PW = 8 - Green PW = 13 - Blue PW = 10 Red PW = 8 - Green PW = 13 - Blue PW = 10 Red PW = 8 - Green PW = 13 - Blue PW = 11

Examining the information presented in Table 4-3, the output data indicates a tolerance value exceeding 20. It is noteworthy that the resulting value lacks consistency, presenting an undesirable characteristic. This output is deemed less than satisfactory as it underscores challenges faced by the color sensor in accurately determining and maintaining consistency in color identification.

Table 4-4 Output for Color Sensor in Dark Color Block and Yellow Light

Ambient Light / Dark Color	Yellow Light
Red	Red PW = 89 - Green PW = 198 - Blue PW = 162 Red PW = 91 - Green PW = 199 - Blue PW = 160 Red PW = 90 - Green PW = 201 - Blue PW = 163 Red PW = 90 - Green PW = 198 - Blue PW = 160 Red PW = 90 - Green PW = 198 - Blue PW = 161 Red PW = 89 - Green PW = 197 - Blue PW = 161 Red PW = 89 - Green PW = 196 - Blue PW = 160 Red PW = 88 - Green PW = 196 - Blue PW = 160 Red PW = 90 - Green PW = 199 - Blue PW = 161 Red PW = 89 - Green PW = 198 - Blue PW = 161 Red PW = 89 - Green PW = 192 - Blue PW = 219 Red PW = 153 - Green PW = 199 - Blue PW = 181 Red PW = 303 - Green PW = 467 - Blue PW = 411 Red PW = 470 - Green PW = 493 - Blue PW = 297 Red PW = 308 - Green PW = 389 - Blue PW = 258 Red PW = 146 - Green PW = 293 - Blue PW = 198 Red PW = 117 - Green PW = 228 - Blue PW = 164 Red PW = 78 - Green PW = 219 - Blue PW = 169 Red PW = 85 - Green PW = 228 - Blue PW = 170 Red PW = 82 - Green PW = 223 - Blue PW = 168 Red PW = 78 - Green PW = 220 - Blue PW = 165 Red PW = 78 - Green PW = 221 - Blue PW = 165 Red PW = 81 - Green PW = 222 - Blue PW = 167 Red PW = 83 - Green PW = 227 - Blue PW = 170 Red PW = 85 - Green PW = 235 - Blue PW = 175 Red PW = 87 - Green PW = 232 - Blue PW = 178 Red PW = 87 - Green PW = 237 - Blue PW = 180 Red PW = 87 - Green PW = 242 - Blue PW = 181 Red PW = 92 - Green PW = 246 - Blue PW = 183 Red PW = 93 - Green PW = 252 - Blue PW = 185 Red PW = 95 - Green PW = 249 - Blue PW = 182
Green	Red PW = 332 - Green PW = 564 - Blue PW = 412 Red PW = 497 - Green PW = 572 - Blue PW = 402 Red PW = 254 - Green PW = 347 - Blue PW = 217 Red PW = 182 - Green PW = 173 - Blue PW = 159 Red PW = 156 - Green PW = 189 - Blue PW = 174 Red PW = 172 - Green PW = 198 - Blue PW = 183 Red PW = 178 - Green PW = 198 - Blue PW = 180 Red PW = 170 - Green PW = 193 - Blue PW = 180 Red PW = 173 - Green PW = 199 - Blue PW = 184 Red PW = 175 - Green PW = 202 - Blue PW = 186 Red PW = 178 - Green PW = 204 - Blue PW = 188 Red PW = 182 - Green PW = 202 - Blue PW = 187 Red PW = 180 - Green PW = 212 - Blue PW = 195 Red PW = 205 - Green PW = 216 - Blue PW = 197 Red PW = 209 - Green PW = 214 - Blue PW = 196 Red PW = 205 - Green PW = 215 - Blue PW = 196 Red PW = 205 - Green PW = 215 - Blue PW = 197 Red PW = 208 - Green PW = 218 - Blue PW = 199 Red PW = 206 - Green PW = 218 - Blue PW = 196 Red PW = 206 - Green PW = 217 - Blue PW = 198 Red PW = 204 - Green PW = 215 - Blue PW = 197 Red PW = 204 - Green PW = 216 - Blue PW = 193 Red PW = 196 - Green PW = 210 - Blue PW = 190 Red PW = 185 - Green PW = 202 - Blue PW = 187 Red PW = 182 - Green PW = 200 - Blue PW = 185

Blue	Red PW = 286 - Green PW = 416 - Blue PW = 161 Red PW = 194 - Green PW = 235 - Blue PW = 154 Red PW = 159 - Green PW = 167 - Blue PW = 82 Red PW = 118 - Green PW = 146 - Blue PW = 77 Red PW = 122 - Green PW = 150 - Blue PW = 85 Red PW = 132 - Green PW = 150 - Blue PW = 84 Red PW = 132 - Green PW = 151 - Blue PW = 85 Red PW = 133 - Green PW = 150 - Blue PW = 85 Red PW = 132 - Green PW = 150 - Blue PW = 84 Red PW = 132 - Green PW = 149 - Blue PW = 85 Red PW = 131 - Green PW = 150 - Blue PW = 85 Red PW = 132 - Green PW = 150 - Blue PW = 84 Red PW = 131 - Green PW = 150 - Blue PW = 84 Red PW = 131 - Green PW = 149 - Blue PW = 84 Red PW = 132 - Green PW = 149 - Blue PW = 84 Red PW = 131 - Green PW = 148 - Blue PW = 84 Red PW = 131 - Green PW = 150 - Blue PW = 84 Red PW = 130 - Green PW = 148 - Blue PW = 84 Red PW = 130 - Green PW = 149 - Blue PW = 84 Red PW = 130 - Green PW = 148 - Blue PW = 84

Upon reviewing the contents of Table 4-4, it is evident that the output data displays an exceptionally high tolerance value exceeding 20. The resulting value is not only substantial but also exhibits considerable inconsistency, rendering this type of output highly unfavorable. In fact, it can be characterized as undesirable and is strongly recommended to be disregarded. This outcome signals a potential issue in the color determination process conducted by the color sensor, necessitating a thorough examination to identify and rectify any underlying problems.

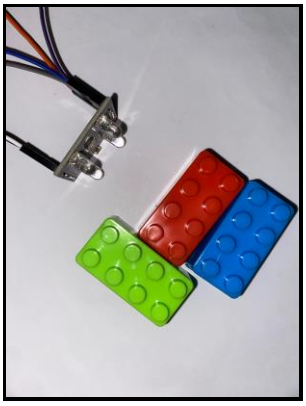

FIGURE 4-6 Bright Color Block

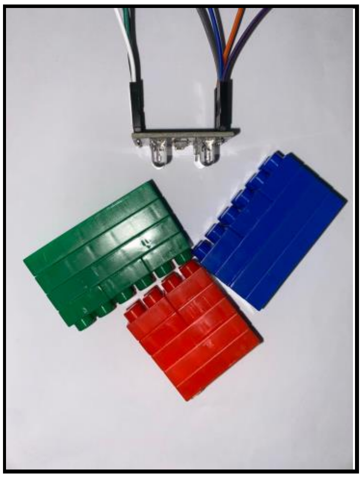

FIGURE 4-7 Dark Color Block

Optimal illumination and accurate color choice play a pivotal role in achieving a distinct output. As evidenced by the data presented in the aforementioned above, it is evident that favorable results are attainable by employing white lights for illumination and selecting vibrant block colors. This strategic combination consistently yields output values within a narrow 10 units tolerance range, underscoring the significance of meticulous lighting and color selection for ensuring clear and reliable outcomes.

4.4 Blynk Application Analysis

In this section, the data derived from the Blynk application is presented. Within the application, the slider icon serves to indicate the degree value of the robot arm, with a maximum limit of 180 degrees. Four sliders are employed to represent each servo motor, namely V0 for the gripper, V1 for the shoulder, V2 for the arm, and V3 for the base.

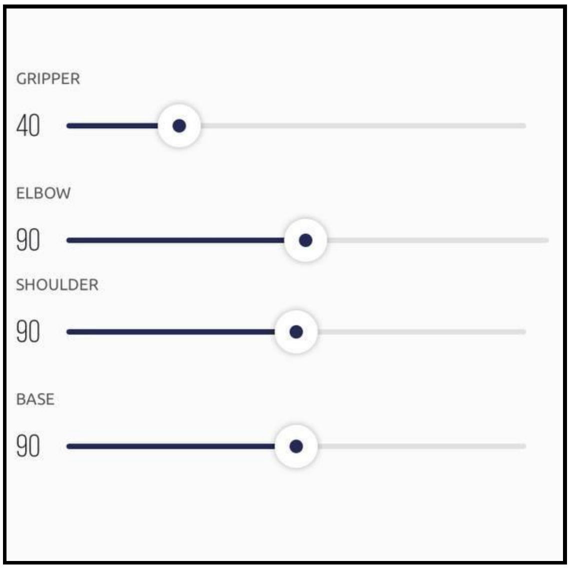

FIGURE 4-8 GRIPPER PART IN 40° IN BLYNK

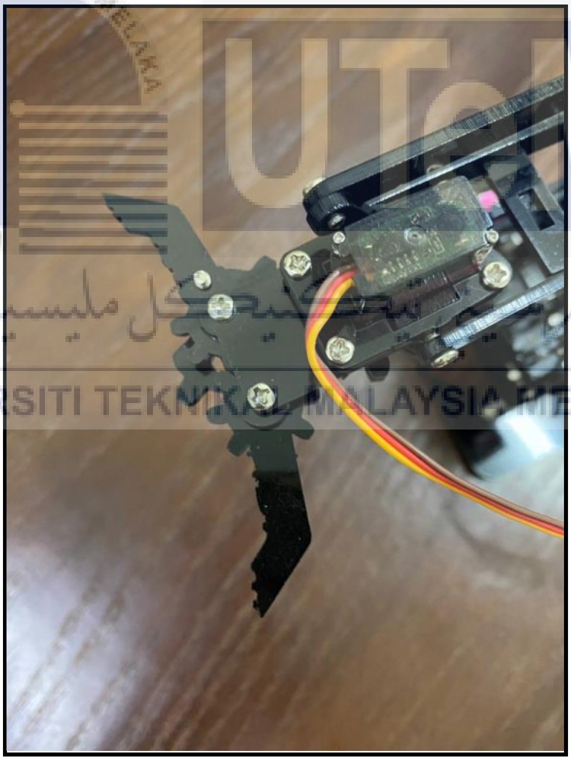

FIGURE 4-9 GRIPPER PART IN 40°

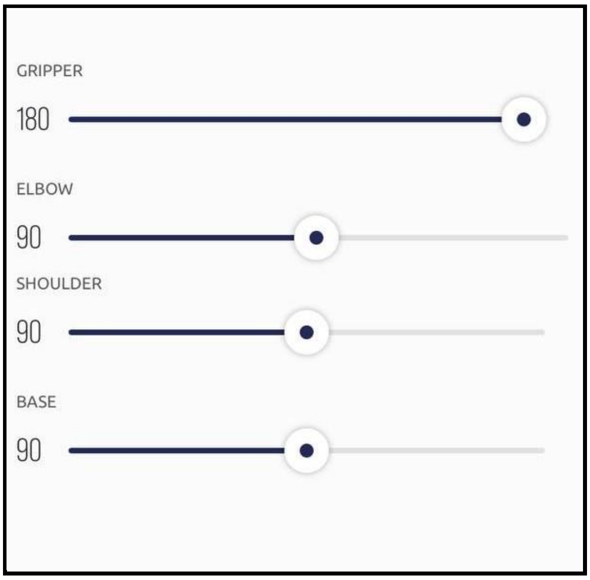

FIGURE 4-10 GRIPPER PART IN 180° IN BLYNK

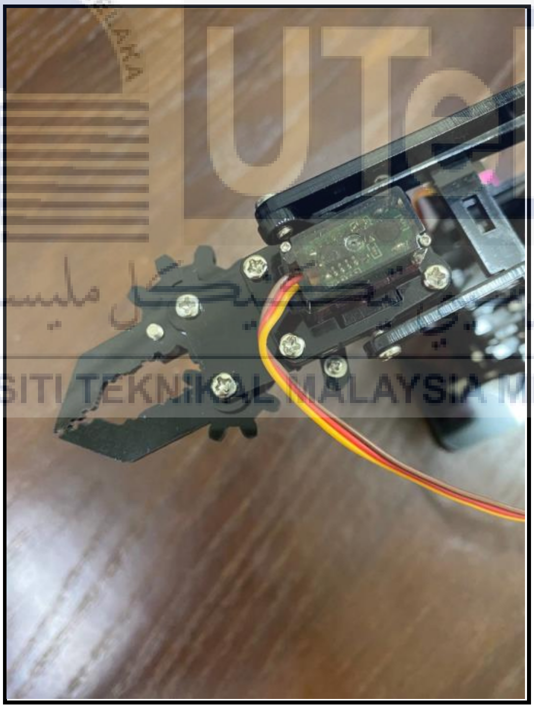

FIGURE 4-11 GRIPPER PART IN 180°

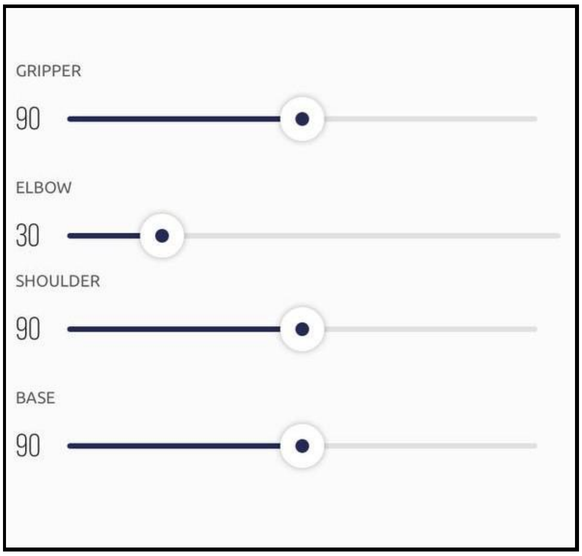

FIGURE 4-12 ELBOW PART IN 30° IN BLYNK

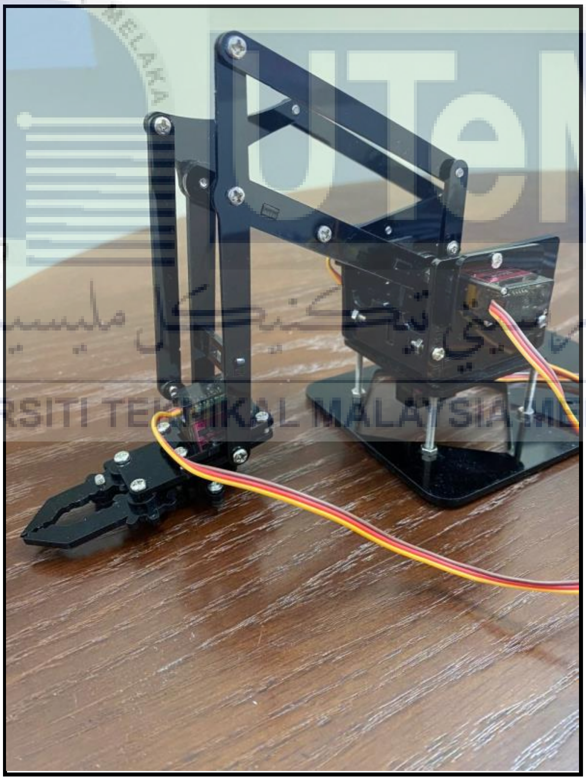

FIGURE 4-13 ELBOW PART IN 30°

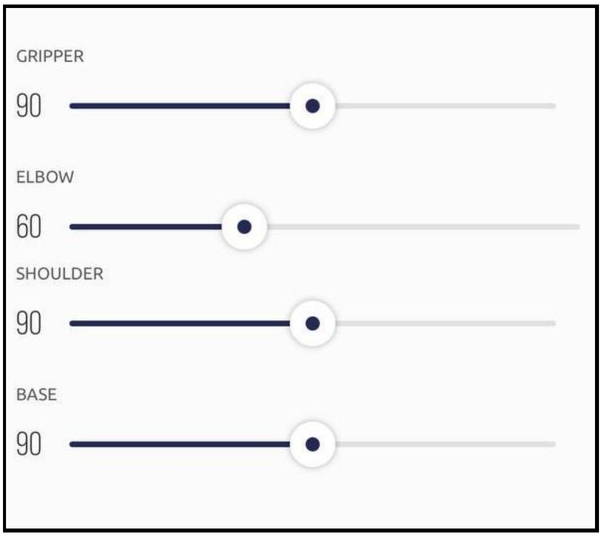

FIGURE 4-14 ELBOW PART IN 60° IN BLYNK

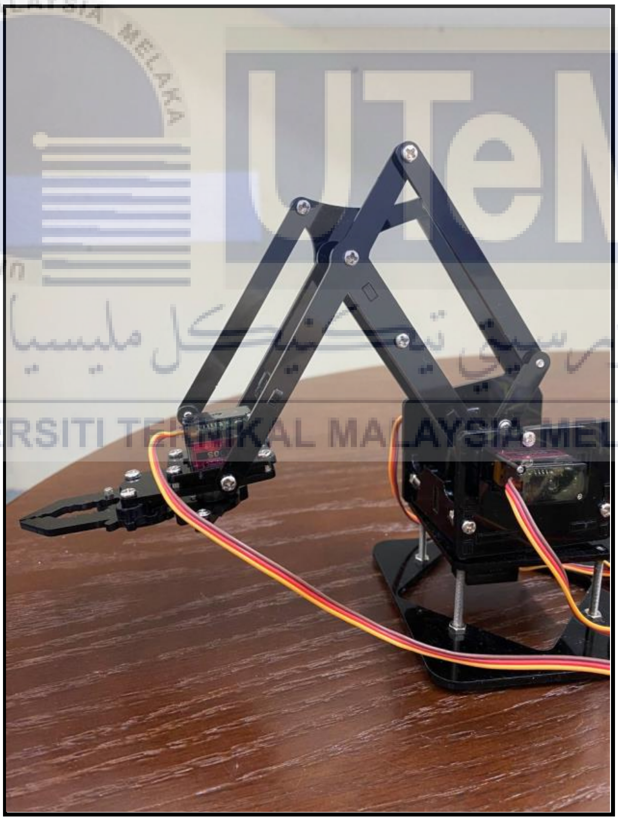

FIGURE 4-15 ELBOW PART IN 60°

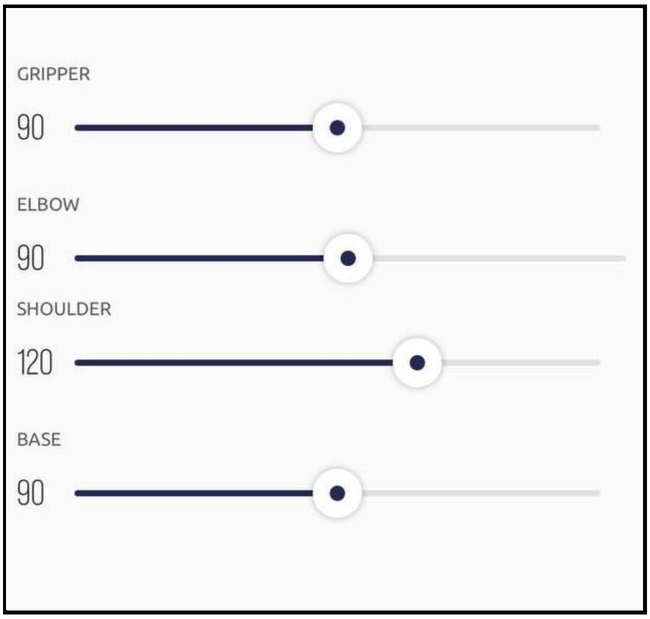

FIGURE 4-16 SHOULDER PART IN 120° IN BLYNK

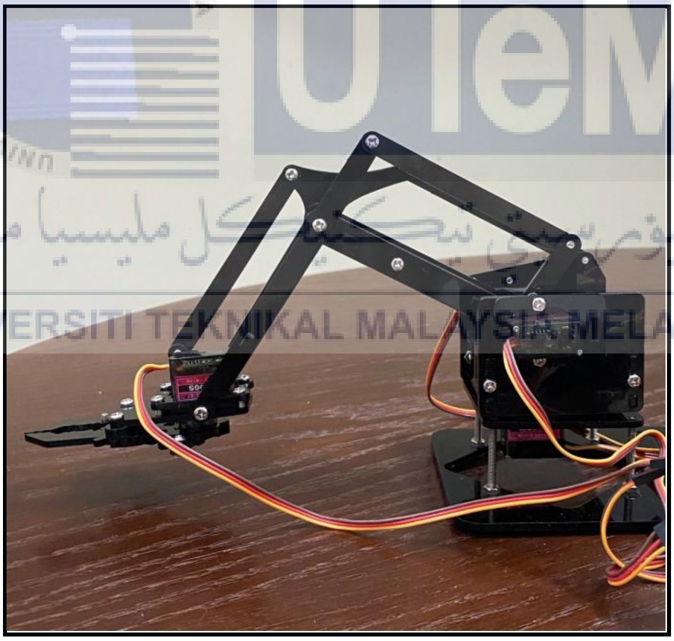

FIGURE 4-17 SHOULDER PART IN 120°

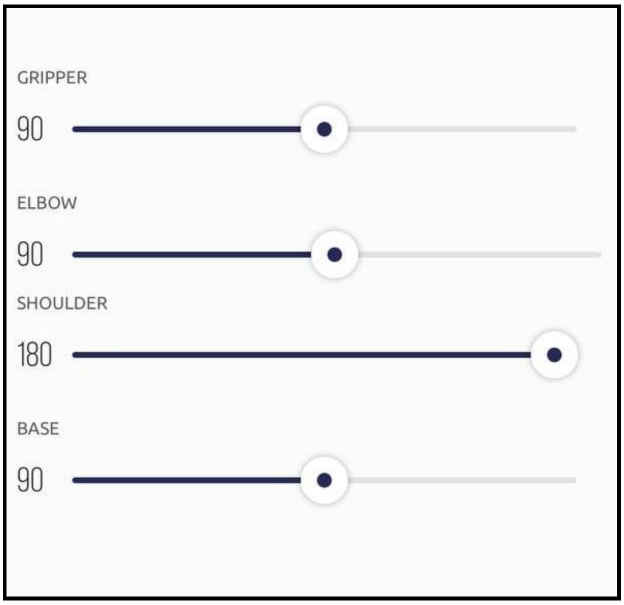

FIGURE 4-18 SHOULDER PART IN 180° IN BLYNK

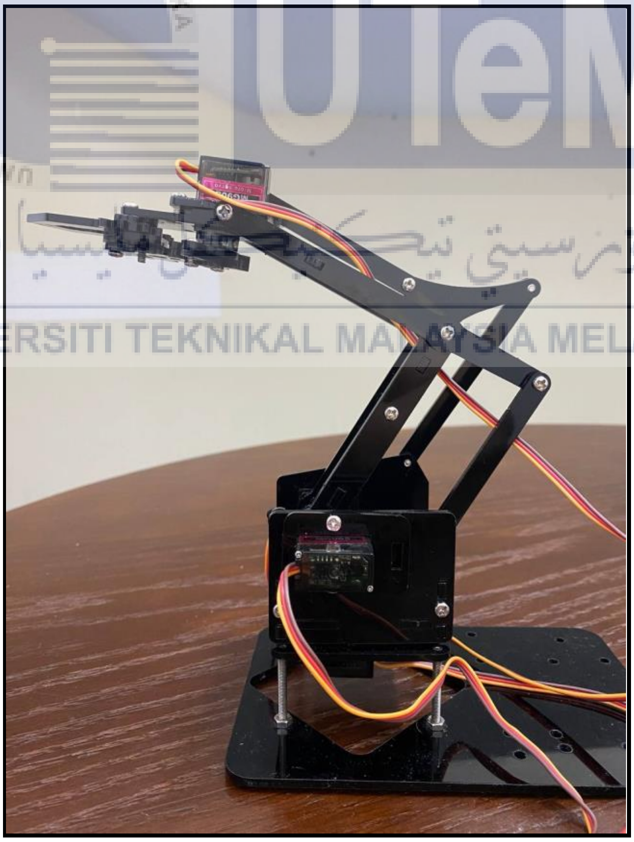

FIGURE 4-19 SHOULDER PART IN 180°

FIGURE 4-20 BASE PART IN 145° IN BLYNK

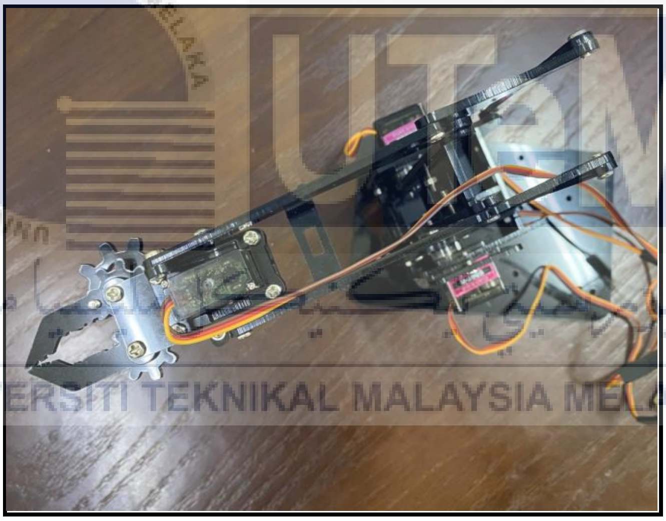

FIGURE 4-21 BASE PART IN 145°

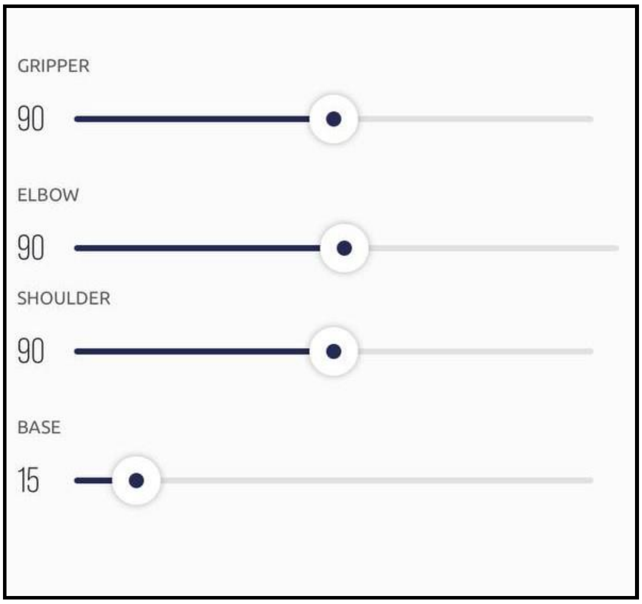

FIGURE 4-22 BASE PART IN 15° IN BLYNK

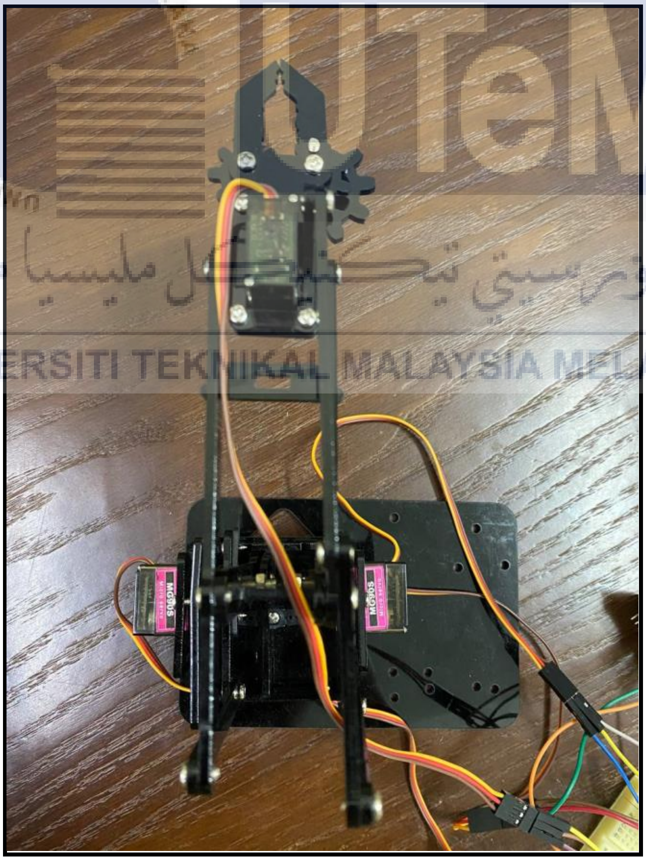

FIGURE 4-23 BASE PART IN 15°

4.5 Summary

In a nutshell, the robot arm demonstrates optimal performance, moving seamlessly in a precise and coordinated sequence. This success is attributed to meticulous attention to angle values and the careful consideration of the specific characteristics and conditions dictated by the accurate color sensor selection. The culmination of these factors ensures the robot arm's ability to navigate in a correct and smooth manner.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Overall, this project has successfully achieved its three outlined objectives in Chapter 3, employing the specified methodology. The Arduino IDE's serial monitor facilitates the monitoring of both color sensor and Blynk outputs. However, a noteworthy concern arose with the servo motor, which is susceptible to burning due to improper wiring and excessive power supply. The MG90s servo motor operates within a voltage range of 4.3V-6V, emphasizing the importance of correct wiring connections and the use of an appropriate power supply to prevent overloading. Additionally, for optimal performance of the TCS 3200 color sensor, it is recommended to use a bright color block under white lighting conditions, ensuring a clear and optimal output from the sensor.

5.2 Future Works and Recommendation

For future enhancements, this project could benefit from the incorporation of a dedicated conveyor system designed to systematically place color blocks, streamlining and expediting the sorting process. The integration of the Blynk application could enable real-time monitoring of color identification based on the color blocks, accompanied by customized notifications for users. Regarding assembly recommendations, meticulous attention and focus are imperative to ensure error-free construction of the robot arm. Careful handling of the servo motor is essential, with precise installation following the correct degree direction and ensuring adequate current voltage to prevent motor burnout.

Opting for brightly colored blocks is highly recommended to maintain a color sensor output tolerance of <20, thereby enhancing the precision of the robot arm in color sorting.

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APPENDICES

APPENDIX 1 Gantt Chart